FIELD ROOTS IN CANADA

CLASSIFICATION, IMPROVEMENT, AND SEED PRODUCTION

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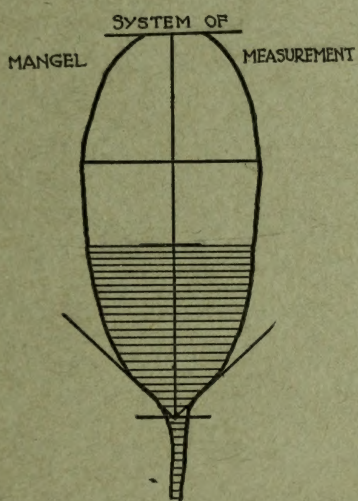
FORAGE CROP DIVISION
EXPERIMENTAL FARMS BRANCH



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DOMINION EXPERIMENTAL FARMS BRANCH

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Carrots in full bloom, Dominion Experimental Station, Summerland

FIELD ROOTS IN CANADA

INTRODUCTION

The term " field roots " is used in Canadian agriculture chiefly with reference to mangels, swedes (rutabagas), turnips and carrots grown principally for the feeding of live stock. The use of the crops specified, as a medium for increasing the succulence of animal rations, has been quite general in the more humid parts of Canada since the pioneer days of this country. That the growing of field roots has not become much more general with advancing years is principally due to the expense incurred in the raising of such crops. Most growers are still in the " sickle " stage in the handling of roots, in that thinning and harvesting are largely done by hand, which practice increases production costs immensely.

The fact that in many sections field corn, sunflowers and annual hays can be handled by the use of modern machinery much more economically than field roots also tends to decrease the acreage that would normally be planted to the latter.

A further cause which contributes to the high cost of production of field roots is the confusion which exists in the nomenclature of the various varieties offered for sale to the grower. The same variety is frequently offered for sale under several names, and what is probably more unsatisfactory from the growers' standpoint, different types are consistently sold under the same variety name. The result is that a type unsuitable to the soil is frequently planted, with an accompanying reduction of yield.

One of the objects of the present bulletin is to present a classification and description of field root varieties offered for sale in Canada that will enable the grower to select a variety suited to his needs with a better understanding of what he is purchasing than has been possible heretofore.

Canadian-grown root seed has compared favourably with the best imported seed in its ability to produce profitable crops. The growing of our own root seed should therefore be a commendable practice. The problem of producing seed of field roots is therefore discussed quite fully in the present publication.

Information concerning the feeding of field roots and cultural practices concerned in their production may be obtained by reference to the bulletin " Growing and Feeding of Field Roots " issued by the Central Experimental Farm.

The writers wish to acknowledge indebtedness to our various Canadian co-workers for information, criticism and helpful advice. Appreciation is also expressed for the untiring efforts of the technical and office staff of the Forage Crop Division in working over the large amount of data incident to the preparation of this bulletin.

HISTORY OF FIELD ROOTS

MANGELS

The mangel appears to be one of the oldest of our cultivated root crops. Although exact records are not available, the production of the mangel can be traced back as far as 2000 B.C.[1] The evidence of its production at that date is contained on an old plate found in an Egyptian grave. This plate represents a labourer placing a large root on a table as a sacrifice. According to Theophrast, red and white roots were commonly cultivated in Asia Minor as far back as 320 B.C.

[1] L. Helweg. " De danske barres-stammar " in Tidskrift for planteavl, Vol. 23, 1916

Both mangels and sugar beets are supposed to be descended from the beach beet, *Beta maritima* L. (*Beta vulgaris perennis* L.), which is found growing wild near the Caspian sea, along the shores of the Mediterranean and in portions of Spain, France, Holland, Great Britain, and Denmark. The beach beet is a perennial but frequently shows a tendency to produce seed the first year. The cultivated types of mangels and sugar beets are considered to be biennial, but according to investigations carried on in other countries[2] little difficulty was experienced in securing seed crops from individual roots for several years in succession.

The root of the beach beet presents a striking contrast to the more highly developed mangel. The shape of the former is long, thin, extremely prongy, and it grows almost entirely under ground. Even the beach beet, however, when grown on deep rich land produces a tap root increased very appreciably in size and succulence. It is quite possible to reconcile the development of our present types from the original beach beet when we consider the prongy mis-shapen types of roots which occasionally result from planting the poorer class of commercial seed of the present day.

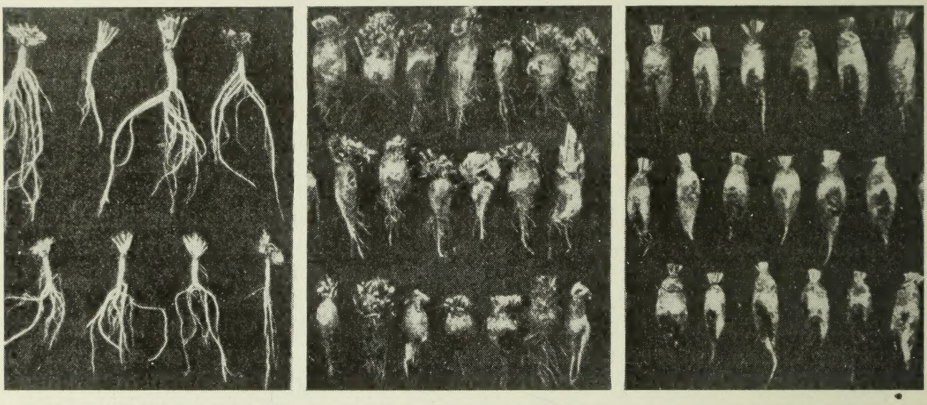

Fig. 1

Original Beach Beet — Degenerated roots from commercial seed — Good type of present-day mangels

The three accompanying pictures illustrate the types of the original beet, some of the variations occurring in the present day commercial seed, and the best type of our present mangel productions.

The origin of many of the strains of mangels has been traced back to the well-known firm, Vilmorin-Andrieux Company, Paris, France (said to have been founded in 1727).[3] This firm cultivated on its estate, "Des Barres," a mangel which was improved by many years of selection, and entered the market in 1853 as "Jaune, Ovoid des Barres" (the yellow egg-shaped from Barres). This variety was exhibited at the International Exhibition in Paris in 1855 and later introduced into Denmark and brought into cultivation there. During the following years it was improved by selection and seed was grown for sale in 1879.

Another strain of mangel of similar shape and colour was the oval-shaped yellow, or Yellow Intermediate, from the firm Peter Lawson & Son, Edinburgh, founded in 1770. This variety is listed in the firm's seed catalogue in 1880 and is supposed to be a very old English or Scotch variety cultivated in Great Britain as early as 1812.

[2] Osteirreich-ungarishe Zeitschrift fur Zuckerindustri und Landwirtschaft, XXIX S. 502.

[3] Harold Faber—"Forage Crops in Denmark", 1920.

Up to the year 1878 the name of Barres had been reserved for Vilmorin's strain alone. At a Danish exhibition in Copenhagen in 1878, however, several strains of mangels were shown, among them the following German varieties: "Oliven-formige gelbe Riesen," "oval flaschenformige gelbe," "Pohls gelbe Riesen," "Gelbe Riesen Flasche." These together with the French "Jaune, Ovoide des Barres," and the English "Oval-shaped yellow," were all very much alike in appearance and became gradually known under the common name of Barres.

How the many strains of Barres of to-day have originated is almost impossible to say. One of the well-known varieties, the Sludstrup Barres, was produced by J. H. Michelsen, a village schoolmaster in Sludstrup, Denmark, in 1896 and is a progeny of a cross between the Vilmorin and Lawson strains.

TURNIPS

(*Brassica Rapa rapifera* L.)

The origin of the turnip is not definitely known, but possibly it originated from *Brassica campestris*. Plinius when dealing with the cultivation of field roots among the Romans says that next to grapes and the cereals the turnip was Italy's most important cultivated plant.[4] It is also known to have been grown in Sweden during the Bronze age.

The first turnips that were introduced into England are believed to have come from Holland in 1550. In the time of Henry VIII (1509-47), according to McIntosh, turnips were used either baked or roasted in ashes and the young shoots were used as a salad and as a substitute for spinach.

The turnip was brought to this continent at a very early date. In 1540, Cartier sowed turnip seed in Canada during his voyage of exploration. In 1779 General Sullivan destroyed the turnips in the Indian fields at the present Geneva, New York, in the course of his invasion of the Indian country.[5]

Both yellow- and white-fleshed varieties of turnips are found in commerce. Some of the former are supposed to be hybrids between the turnip and swede.[6]

SWEDE TURNIP OR RUTABAGA

At the present time this plant is grown practically all over the world and is considered to be a descendant of rape (*Brassica napus* L.). Darwin says *B. napus* L. "has given rise to two large groups, namely Swedish turnips (thought by some to be of hybrid origin) and Colzas, the seeds of which yield oil." It seems reasonable to assume that the Swedish turnip may have originated in its varieties from *B. campestris* hybridized with *B. napus.*

The rutabagas of our gardens include two forms, one with white flesh, the other with yellow. The French call these two classes, chou-navets and rutabagas respectively. The English nomenclature, while now including the two forms under a common name, formerly classed the first as the turnip rooted cabbage. In 1806, this distinction was retained in the United States, McMahon describing the turnip rooted cabbage and the Swedish turnip or rutabaga.

The rutabaga is said by Sinclair to have been introduced into Scotland about 1781-2, and a quotation in the Gardener's Chronicle claims that it was introduced into England in 1790. It is mentioned in 1806 by McMahon as being grown in American gardens, and in 1817 there is a record of one acre of this crop in Illinois. The vernacular name indicates an origin in Sweden or Northern Europe. It is called Swedish turnip or Roota-baga by McMahon 1806, by Miller's Dictionary 1807, by Cobbett 1821, and by other authors to the present time.[7]

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[4] Gustav Sundelin "Foderrotfrukterna, deras foradling och odlingsvarde" 1923.

[5] Sturtevant's "Notes on Edible plants", 1919.

[6] Percival. Agricultural Botany, 1910.

[7] Sturtevant's "Notes on Edible Plants", 1919.

CARROTS

Long before the Christian era the merits of the carrot as a medicinal plant were recognized by the human inhabitants of the Old World.[8] As people gave up the nomad life and settled down to cultivate plants, this crop was one of the first to come under cultivation. This is indicated by the fact that the carrot was well known to and cultivated by the early Roman and Germanic tribes.

The first author who distinguished carrots from parsnips was the Roman surgeon Dioscordies who lived in the first century A.D. He was a military surgeon, who on his many travels during the Roman wars had the opportunity of seeing and describing a large number of medicinal plants. He gave the carrot the name of Stafylinos and the parsnip Elafoboskon. The name Stafylinos seems however, to have existed even prior to Dioscordies' time and is a Grecian name, which in literal translation means "the grape resembling." The only plant this description can be applied to is the violet or purple carrot and his description is so remarkably striking that no doubt Dioscordies himself had seen this type.

Theophrast in 320 B.C. mentions a plant which he calls Stafylinos, but it is not certain whether he meant carrot, parsnip or some other related plant. Whether the purple carrot has been known still earlier is impossible to say, but Theophrast is the first author, of whom we have record, to use the name Stafylinos.

While the white-fleshed carrot seems to be the only type apart from the purple that was known in the early ages, from the end of the middle age and into the beginning of the eighteenth century the yellow carrot seems to have been the most common. The red carrot is mentioned for the first time in 1471 by Petrus de Crescentis. In an English publication by J. Parkinson 1629 it is shown that long and short types of carrots were not unknown and the author is especially recommending a red variety. Light and deep coloured yellow varieties are also mentioned. A hundred years later in 1740 Heinrich Hesse a German writer, mentioned different varieties both with regard to colour, shape and time of maturity. It is estimated that the well-known varieties, Champion, Rhinsk, Surrey and James were put on the market some time between 1840 and 1860.

The violet or purple carrot which maintained its existence from the earlier ages, through the whole middle age, and up to the beginning of the 19th century has entirely disappeared after more than two thousand years of cultivation.

The evidence that the purple and white carrots were the first varieties put into cultivation, followed by the yellow and later on by the red coloured varieties, naturally leads to the assumption that the red type was developed by a cross either between the purple and white or between the purple and yellow.

In order to establish how the red carrot was developed, L. Helweg started some hybridization experiments in 1895 and after about ten years of experimentation came to the conclusion that the red carrot is a progeny of a cross between the yellow and the purple varieties.

The cultivated types of carrots all appear to have descended from *Daucus carota* L. which can be found growing wild in most districts of Europe and the western parts of Asia. This is evidenced by Vilmorin[9] and Hoffman[10] who both claimed a fair measure of success in bringing cultivated varieties back to the original wild state with extremely prongy and woody taproots and also, through extensive cultivation, succeeded in reshaping the wild carrot into a smooth, fleshy and palatable root.

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[8] L. Helweg De Dyrkede Gulerodsformer, 1908.

[9] Vilmorin " Le bon jardinier, 1838 ".

[10] Hoffman " Botanische Zeitung 34."

DISTRIBUTION OF FIELD ROOTS

Field roots are grown in every province in the Dominion. By far the largest proportion, however, are raised in the Eastern Provinces.

The extent to which field roots are produced in the various provinces can be best illustrated by the inclusion of a table giving the acreage of field roots in Canada, by provinces, from the years 1919 to 1926 inclusive as reported by the Dominion Bureau of Statistics.

TABLE I.—ACREAGE OF FIELD ROOTS IN CANADA

Year	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Nova Scotia	Prince Edward Island	Total
1919	7,387	12,500	13,932	6,045	123,029	87,496	24,279	30,291	12,337	317,296
1920	7,403	12,300	10,449	7,404	119,744	83,613	20,030	19,946	9,397	290,286
1921	6,809	8,202	7,870	4,411	104,157	53,084	17,745	15,436	9,961	227,675
1922	7,347	9,289	8,666	4,630	105,033	48,812	16,202	16,162	8,115	224,256
1923	7,188	9,254	5,235	4,987	102,091	33,948	10,799	12,382	8,628	194,512
1924	6,435	6,559	5,364	4,619	108,196	33,600	10,657	12,643	9,847	197,920
1925	6,919	8,555	4,876	4,732	110,538	34,000	11,711	13,353	9,692	204,376
1926	6,780	8,596	3,387	4,411	107,181	34,000	12,235	14,858	10,334	201,782
Average	7,034	9,407	6,347	5,155	109,996	51,069	15,457	16,884	9,789	231,138

An examination of the data contained in table 1 will indicate that but little change has taken place in the total acreage produced by the different provinces during the past five or six years. It is also quite evident that the acreage of field roots produced on the Prairie Provinces is very limited, compared with the cropped areas of that district.

The bulk of the field roots raised in Canada are used for feeding animals and appear to be appreciated most highly in this connection by the dairymen of the country. This being the case it was thought that some relationship should exist between the acreage of field roots produced and the number of dairy cows kept per acre of cultivated land. Table 2 presents data indicating the relationship between the acreage of field roots and the total amount of cultivated land for each province.

TABLE 2.—ACREAGES OF FIELD ROOTS AND NUMBER OF DAIRY COWS IN RELATION TO ACREAGE OF CROPPED LAND

(Average of years 1920–25 inclusive)

Province	Acres cropped land per milch cow	Acres cropped land per acre of field roots
Prince Edward Island	10·27	57·34
Nova Scotia	5·35	51·03
New Brunswick	8·31	72·30
Quebec	13·24	151·92
Ontario	8·39	94·45
Manitoba	27·54	1,321·00
Saskatchewan	46·10	2,829·32
Alberta	24·77	1,109·39
British Columbia	5·70	53·93

The data in table 2 show a marked correlation between the number of acres per cow and the proportion of field roots raised per acre of cropped land. The extremely small proportion of field roots per acre of cropped land in the Prairie Provinces, particularly in the province of Saskatchewan, and also the large amount of land per milch cow, is strikingly illustrated. It seems quite possible that as diversified farming becomes more generally adopted and the proportion of dairy cows per acre of cropped land increases that there will be an increase also in the acreage of field roots raised.

It should be evident to any person who has had the opportunity of investigating the facts of the matter that field roots have been in the past quite expensive to produce. It should be just as evident, however, that it is within the power of the growers to lessen these production costs very materially. This can be accomplished in a number of ways. A better understanding of the relationship between type of root and its adaptation to a particular soil would result in largely increased yields and accompanying decrease in cost per ton. A further possibility of decreasing the cost of producing field roots lies in the use of machinery for performing work now down by hand. There seems no reason why a machine for blocking out the young roots should not be in general use or why machinery could not be developed for pulling, topping and piling field roots in a single operation. A number of such machines have been reported already to the Forage Crop Division and it is expected that in the near future some of these will be perfected to a point where they will be worthy of much more general use. The utilization of the tops of the roots as well as the root itself would also be accompanied by a very appreciable reduction in the production costs of the various roots crops. While in some cases the feeding value of the tops are appreciated and use is made of this part of the plant, in the majority of instances the tops are simply allowed to go to waste, the only value derived from them being their fertilizing effect when ploughed under. In the case of an average crop of mangels, around 3 to 4 tons of tops are left on the field. This tonnage of tops either ensiled or fed green would produce returns sufficient to cut down at least a portion of the cost of producing the root crop.

Unless growers are willing to consider seriously the question of lowering the cost of production of field roots the outlook for the profitable raising of such crops in the future does not look very promising. Of course the sections which are engaged in the raising of swedes for human consumption mostly receive a sufficiently high return for their product to enable them to carry on with a reasonable profit.

In connection with the production and sale of all kinds of field roots it is quite apparent that a multiplicity of unnecessary names exists. Such a condition is evidently not in the best interests of the field root industry. It is true that under existing practices old varieties may be exploited under new names with some degree of immediate profit by seedsmen. The ultimate success of a variety is, however, its utility to the grower and the ultimate success of a seedsman is his ability to establish a bond of confidence between himself and the men to whom he sells his produce. It would appear that this could best be brought about by a common agreement among seedsmen to adopt a standard name for all field roots possessing similar morphological characteristics. Selected strains of any variety, which possessed some physiological character such as increased yielding capacity or resistance to disease, could be differentiated from the standard variety by the addition of an adjective descriptive of its superiority. For example all varieties of swedes of the Bangholm type would retain the name Bangholm. In the case of the club-root-resistant strains either a number or distinguishing name could be added to the Bangholm with an explanation on the part of the seedsmen as to what this number or descriptive word or words meant in the way of additional desirability.

CLASSIFICATION

Obvious confusion exists with regard to so-called varieties of field roots as sold throughout Canada at the present time. In an endeavour to bring order out of this confusion an analysis of field root varieties was undertaken by the Forage Crop Division of the Central Experimental Farm and a mechanical classification has been attempted, based on over fifty thousand measurements.

An examination of the seed catalogues listing field roots for sale will reveal the frequent use of certain descriptive terms. Reference to the mangel crop

will serve to illustrate this point. Included in the variety name or used in connection with a description pertaining to the variety we usually see one of the following six terms: long, half-long, intermediate, tankard, ovoid, and globe. These terms are used to indicate the general type of the root. The mechanical classification which we wish to present has been based on an attempt to obtain sufficient measurements and general notes concerning the types as indicated by the seed catalogues to clearly define them.

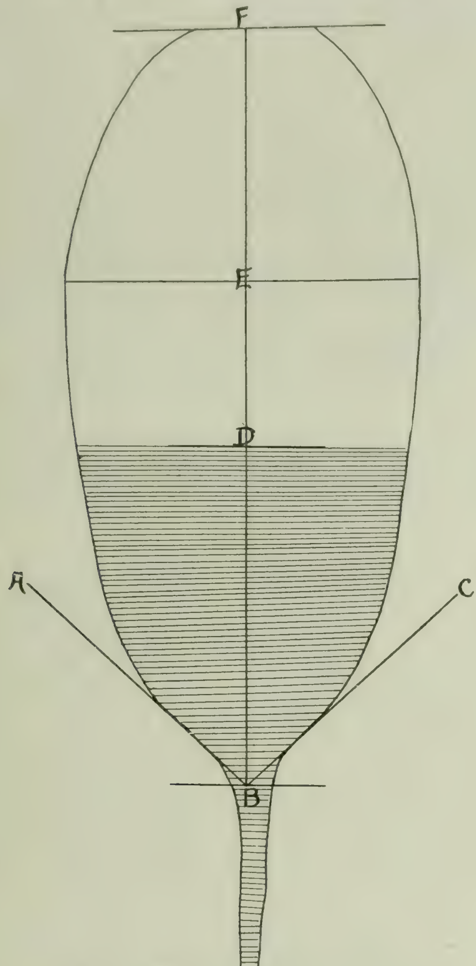

FIG. 2.—System of measurement.

Figure 2 illustrates our system of measurement. The junction of the lines of A B and C B, which lines are drawn parallel with the line of slope at the base of the root, indicates the point which is considered in all types to be the lower termination of the root in question. The following four measurements were made on all roots under investigation: (1) length; (2) width taken at the widest part of the root; (3) distance of the root in the ground, which is the distance from B to the ground line D; (4) distance from B to the widest part of the root.

Only mature roots were used for type measurements, as we found that roots which were decidedly small and immature did not show the same relationship of parts that they presented later in the season.

The actual length, width, or depth in the ground of any root is not enough in itself to determine the general type to which it should belong. It is rather

the relationship between these measurements that is important from the standpoint of classification. In order to reduce the various measurements to a common standard the width, depth in ground, and distance to the widest point were all divided into the length of each individual root. In this manner the length-width, length-depth in ground, and length-distance to widest point ratios were obtained. The length-width and length-depth in ground ratios were used as the primary basis for type determination.

Seed of mangels, swedes, turnips, and field carrots were obtained from all of the leading firms carrying the seed of such crops in Canada; also from representative seed firms in Great Britain and Europe. Representative roots from the most uniform of these various varieties were selected and the types were determined by averaging similar measurements from varieties or strains belonging to a common type.

CLASSIFICATION FOR MANGELS

The averages secured from all of the measurements taken from the mangel crop during the course of three years are included in table 4.

TABLE 4.—MANGELS—AVERAGE OF ALL MEASUREMENTS

Type	Year	Length-Width		Length-Depth		Length-Distance to widest point	
		Range	Ratio	Range	Ratio	Range	Ratio
Long	1923 1924 1925	2·6–5·5 3·0–5·5 2·6–5·5	3·310 4·033 3·511	1·4–2·6 1·5–2·6 1·4–2·6	1·981 2·206 1·992	1·0–2·0 1·1–1·9 1·2–2·0	1·279 1·401 1·398
Average			3·618		2·059		1·359
Half-Long	1923 1924 1925	2·0–3·3 2·0–3·3 2·0–3·1	2·915 2·794 2·510	1·4–3·0 1·4–3·0 1·5–3·0	2·044 2·190 2·201	1·0–2·4 1·0–2·1 1·2–2·4	1·329 1·473 1·570
Average			2·739		2·145		1·457
Intermediate	1923 1924 1925	1·0–2·8 1·6–2·7 1·9–2·8	2·065 2·114 2·484	1·6–3·3 2·0–3·3 1·7–2·9	2·261 2·840 2·155	1·0–2·4 1·3–2·0 1·3–1·6	1·511 1·561 1·464
Average			2·221		2·418		1·512
Ovoid, Average	1924–25	1·2–2·6	1·823	1·6–2·4	2·389	1·1–2·5	1·648
Globe	1923 1924 1925	0·8–1·4 1·0–1·4 0·8–1·4	1·074 1·116 1·119	2·0–3·0 2·0–3·0 2·0–3·0	2·405 2·420 2·453	1·3–2·3 1·3–1·9 1·4–2·3	1·597 1·482 1·790
Average			1·103		2·426		1·623
Tankard	1923 1924 1925	1·1–2·3 1·1–2·3 1·2–2·3	1·594 1·727 1·700	2·3–4·0 2·3–4·0 	3·088 3·283 5·181		
Average			1·674		3·850		

There appears to be a reasonably distinct basis of mechanical classification with regard to the various classes of mangels as indicated by the seed catalogues. Thus the length-width ratios and length-depth in ground ratios of the long mangel are distinctly different from that of the other types. The same comments would apply to all of the types concerned, each being distinct from the other. The varieties classed under the long types, however, appear to grade into the half-long and the half-long into the intermediate. There is a consequent over-lapping of types. The averages, never the less, of all the individuals belonging to any type are quite distinct.

To illustrate more clearly the differences recorded in table 4, figures showing representative individuals of the type are included. These are super-imposed

on a ground-line and so located that they demonstrate the average proportion of such roots normally found above and below the ground.

An examination of these individual roots will bear out the fact that the types as illustrated represent more than purely mechanical divisions. Each particular type has a different proportion of the root in the ground and in many cases also a different general structure of the root. Such variations have a definite bearing on the adaptability of the type in question to various kinds of soil. The shallow-rooted types represented by the tankard and globe are obviously better suited to shallow soil than the long or half-long types. These same long and half-long types, however, seem to be able to reach proportionately greater development on deep rich soils than the shallow-rooted sorts.

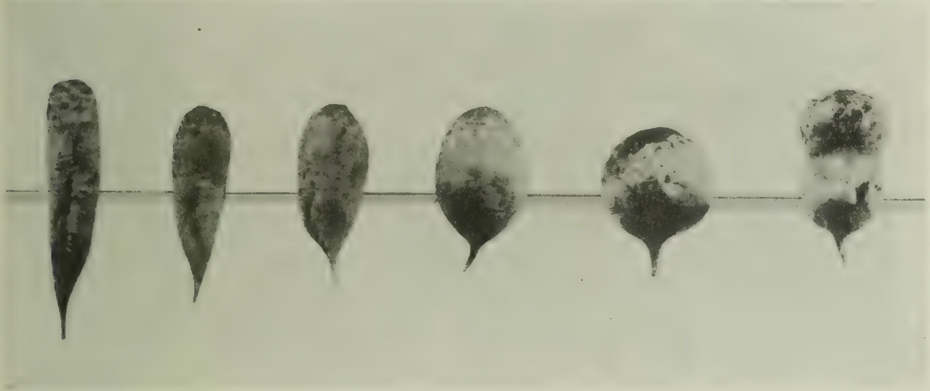

FIG. 3.—Mangel types

In discussing the adaptation of root types to soil, it seems opportune to emphasize the desirability of applying the term tankard only to mangels having a root with an abrupt termination. The majority of tankard types are usually more or less rectangular and frequently constricted in the middle, although they may also be parallel sided or slightly convex sided. Such types are distinctly shallow-rooted, easy to harvest and well adapted to shallow soils. The fairly common practice of seedsmen applying the name tankard to types which properly belong in the intermediate class is undesirable and misleading.

The variation in ratios existing within the different classes of roots is due to a number of causes. There are changes in shape caused directly by varying soil conditions, but we believe that the greatest variation is due to genetic impurity of the varieties being tested. In an open-textured, fairly rich soil which gives every opportunity for the normal development of any root, the uniformity within the variety appears to be in direct ratio to its genetic purity.

The mechanical classification offered does not take into account the third measurement which was secured, namely the distance from the base of the root to the widest point. It is quite possible to have roots within the intermediate type as determined by the length-width and length-depth in ground ratios showing variations in shape. Such variations will be dependent largely on the location of the widest portion of the root and on whether or not this widest portion occurs in a restricted section of the root or is carried fairly well throughout its whole length. Certain well defined variations in the conformation of the different classes of roots are illustrated in figs. 4, 5, 6, 7.

In addition to the variation in shape there are corresponding variations in colour and other morphological characteristics.

A classification of the more common mangel varieties offered for sale to Canadian growers is included at this point which indicates varieties which appear to be similar as far as distinguishable morphological characteristics are concerned.

FIG. 4.—Some of the variations occurring in the long (upper) and half long (lower) mangel types.

FIG. 5.—Some of the more common variations occurring in the intermediate type of mangels.

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Fig. 6.—Some variations of the tankard type of mangel.

FIG. 7.—Variations in the shape in the globe and in the ovoid (lower two) types of mangels.

TABLE 5.—CLASSIFICATION OF THE MORE COMMON VARIETIES OF MANGELS FOR SALE IN CANADA

Variety	Type						Colour																								
							Skin													Flesh				Top							
							Above ground							Below ground																	
	Long	Half-Long	Intermediate	Ovoid	Globe	Tankard	Nopal red grading into pale smoke grey	Olive yellow to olive ochre grading into pale smoke grey	Old rose grading into Japan rose and pale smoke grey	Lime green grading into pale smoke grey	Flame scarlet grading into pale smoke grey	Oxblood grading into pale smoke grey	Nopal red	Wax Yellow	White grading into old rose	White	Flame scarlet	Oxblood red	Cadmium orange	White with begonia rose rings	White	White with wide cadmium yellow rings	Carmine with white rings	White with sometimes traces of cadmium yellow in rings of root below ground	Forest green leaves, stems with varying intensities of begonia rose	Inner leaves showing stems and veins with cadmium yellow—Remaining part forest green	Forest green with lower parts of stems showing tinge of old rose	Forest green	Forest green. Stems of all leaves tinged with cadmium yellow, young leaves more than older ones	Stems carmine. Leaves maroon	Entirely forest green, very slight tint of cadmium yellow on young leaves
Prize Mammoth Long Red	x						x						x							x					x						
Elevetham Long Red	x						x						x							x					x						
Long Red Mammoth	x						x						x							x					x						
Mammoth Long Red	x						x						x							x					x						
Gatepost	x						x						x							x					x						
Long Red	x						x						x							x					x						
Elevetham Mammoth	x						x						x							x					x						
Giant Long Red	x						x						x							x					x						
Long Yellow	x							x						x							x					x					
Giant Sugar Rose		x							x						x						x						x				
Select Giant Rose—Intermediate Sugar		x							x						x						x						x				
Giant Sugar		x							x						x						x						x				
Svalof Original Rubra		x							x						x						x						x				
Royal Giant Sugar Beet		x							x						x						x						x				
Giant Rose Sugar		x							x						x						x						x				
Giant Half Sugar		x							x						x						x						x				
White Red Top Half Sugar		x							x						x						x						x				
Sugar Beet or Half Sugar Rose		x							x						x						x						x				
Red Half Sugar		x							x						x						x						x				
Half Sugar Marienlyst No. 5		x							x						x						x						x				
Giant White Sugar		x								x						x					x							x			
Giant White Feeding		x								x						x					x							x			
Monarch Sugar		x								x						x					x							x			
Sugar Mangold		x								x						x					x							x			
Giant White Half Sugar		x								x						x					x							x			
Giant Sugar Beet or Half Sugar White		x								x						x					x							x			
Select Giant White Sugar		x								x						x					x							x			
Svalof Original Alfa		x								x						x					x							x			
White Green Top Half Sugar		x								x						x					x							x			
Giant White Feeding Sugar		x								x						x					x							x			

Giant Sugar White		x								x						x					x							x			
New Combination			x									x						x					x							x	
Mammoth Red Intermediate			x				x						x							x					x						
Red Intermediate			x				x						x							x					x						
Giant Red Sugar			x				x						x							x					x						
Leviathan			x				x						x							x					x						
Red Intermediate			x								x						x					x							x		
O.A.C. Yellow Leviathan			x					x						x							x					x					
Peerless			x					x						x							x					x					
Sludstrup Barres			x					x						x							x					x					
Barres Stryno			x					x						x							x					x					
Giant Yellow Intermediate			x					x						x							x					x					
Rosted Barres			x					x						x							x					x					
Yellow Intermediate			x					x						x							x					x					
Ferritslev Barres			x					x						x							x					x					
Golden Giant Intermediate			x					x						x							x					x					
Barres Tystofte			x					x						x							x					x					
Danish Sludstrup			x					x						x							x					x					
Manitoba Giant Yellow			x					x						x							x					x					
Barres Slustrup			x					x						x							x					x					
Giant Yellow Half Long Intermediate			x					x						x							x					x					
Taaroje Barres			x					x						x							x					x					
Sunrise			x					x						x							x					x					
Champion or Gatepost			x					x						x							x					x					
Yellow Leviathan			x					x						x							x					x					
Red Globe					x		x						x							x					x						
New Century					x						x						x					x							x		
Perfection					x						x						x					x							x		
Golden Globe					x						x						x					x							x		
Mammoth Golden Globe					x						x						x					x							x		
Special Yellow Globe					x						x						x					x							x		
Large Yellow Globe					x						x						x					x							x		
Devon. Champion Yellow Globe					x			x											x					x							x
Yellow Globe					x			x											x					x							x
Giant Yellow Globe					x			x											x					x							x
New Smithfield Yellow Globe					x			x											x					x							x
Prizewinner Yellow Globe					x			x											x					x							x
Large Yellow Globe					x			x											x					x							x
Devon Yellow Globe					x			x											x					x							x
Superlative					x			x											x					x							x
Champion Yellow Globe					x			x											x					x							x
Non Such					x			x											x					x							x
Prizetaker Yellow Globe					x			x											x					x							x
Red Eckendorffer						x	x						x							x					x						
Eckendorffer Red						x	x						x							x					x						
Red Tankard						x	x						x							x					x						
Golden Tankard						x					x						x					x							x		
Golden Fleshed Tankard						x					x						x					x							x		
Eckendorffer Yellow						x		x											x					x							x
Yellow Eckendorffer						x		x											x					x							x
Ideal						x		x											x					x							x
Eclipse						x		x											x					x							x
Q. Q. Mangel						x		x											x					x							x
New Ideal						x		x						x							x					x					
White Knight						x		x						x							x					x					

By reference to table 5 a grower may select a number of varieties, any one of which should give him almost identical results. In the event of inability to secure a variety found suitable for the peculiar soil and climatic conditions on any farm, substitutes can be quite easily selected, with a reasonable assurance that this substitute will be identical with the original variety in outward appearances at least.

A consideration which is quite frequently lost sight of by growers of field roots is the labour entailed in the pulling of the different types. Our experience in handling hundreds of lots of mangels convinced us that there was a great deal of difference in the relative amounts of energy required to extract representatives of different types. In order that we might verify our supposition numerous pulling tests were conducted. Both the amount of straight pull and the amount of pull exerted sideways to extract representative roots of the various types was determined. The data secured are recorded in table 6.

TABLE 6.—RELATIVE ENERGY USED IN EXTRACTING DIFFERENT TYPES OF MANGEL FROM THE SOIL

Type	Straight Pull			Side Pull		
	Number of roots extracted	Average pull per root in pounds	Pull per acre 23,200 roots	Number of roots extracted	Average pull per root in pounds	Pull per acre 23,200 roots
			tons lb.			tons lb.
Long	100	50·07	580 1,624	100	37·15	430 1,880
Half-long	101	40·22	466 1,104	100	22·63	262 1,016
Intermediate	185	34·22	396 1,904	122	24·87	288 984
Ovoid	20	31·15	361 680	12	22·92	265 1,744
Globe	101	32·15	372 1,880	101	17·31	200 1,592
Tankard	88	24·28	281 1,296	110	18·49	214 968
Total number of roots extracted	595	....	....	545	....	....

As the type of soil influences the amount of pull necessary to extract any root the figures recorded in table 6 indicate the relative resistance to extraction rather than the actual amount of pull that one might expect to experience on soil types differing from that on which the test was conducted.

The amount of pull per individual root is quite marked for the extreme types, over twice the amount of pull being necessary to extract a long type than is required to extract a tankard type. Figuring on the basis of 23,200 roots to the acre, which number would constitute a perfect stand under our conditions of planting, the total difference in pull per acre between the different types is quite striking. It should be obvious that it is much more expensive to pull the long types than the tankard, if the comparison is based on the relative amounts of energy expended in the operation of pulling.

CLASSIFICATION FOR SWEDES

Swedes as commonly grown by the Canadian farmer do not present the extensive variations in shape, size and colour that prevail in the case of mangels. So many of the varieties approach globe or ovoid shape that this particular conformation is commonly recognized as the standard for all swedes. Within this general ovoid shape, however, there are well defined differences which have been separated by a large number of measurements into the following types: globe, flat, ovoid, and tankard. The ratios and range of measurements found within reach of these types are presented in table 7.

TABLE 7.—SWEDES—AVERAGES OF ALL MEASUREMENTS

Type	Year	Length-Width		Length-Depth		Length-Distance to widest point	
		Range	Ratio	Range	Ratio	Range	Ratio
Globe	1924	0·9–1·3	1·079	1·3–2·5	1·808	1·2–1·8	1·442
	1925	1·0–1·3	1·091	1·7–2·5	2·221	1·3–1·8	1·512
Average			1·085		2·015		1·477
Flat	1924	0·5–1·0	0·769	1·3–8·5	1·789	1·1–1·9	1·473
	1925	0·6–1·0	0·790	1·9–3·0	2·645	1·2–1·8	1·534
Average			0·780		2·217		1·504
Ovoid	1924	1·1–2·1	1·507	2·0–3·5	2·502	1·3–2·3	1·649
	1925	1·2–2·0	1·570	2·1–3·5	2·717	1·3–2·1	1·583
Average			1·539		2·620		1·616
Tankard	1924	1·0–1·9	1·354	2·2–4·0	2·836	1·5–2·5	1·907
	1925	1·0–1·7	1·419	2·3–4·0	3·417	1·7–3·0	2·425
Average			1·387		3·127		2·166

The essential difference between the types as indicated by the data presented in table 7 is a matter of difference in the length-width ratio. In the case of the globe types the length and width are almost equal. With the flat types the width exceeds the length considerably, whereas with the ovoid types the length exceeds the width to an appreciable degree. The tankard is essentially an ovoid type in which the sides may be nearly parallel, slightly convex, or slightly concave. In common with the corresponding type of mangel, the proportion of the root in the ground is less than with the other types, although this difference is not nearly as marked as in the case of the mangel.

There is, in fact very little difference in the average depth in the ground of the various swede types; as a consequence there does not seem to be the same relationship between type and suitability to different soils as exists with mangels. Pulling tests conducted with a large number of swede varieties bear evidence to the fact that the number and distribution of the main and secondary roots of this crop has a much greater correlation with the amount of pull necessary to extract the root than has the type of root itself.

The physiological considerations of yield, freedom from disease, and climatic adaptation, have thus a greater significance in selecting a variety than has the particular type as differentiated in the mechanical classification presented. Occasionally strains of a variety will give profitable increases in yield over the mother type even though resembling it in visible characteristics. Resistance to disease, particularly in the case of resistant varieties in club-root-infested areas will also give marked increases in yield.

A table of classification is included which presents the different varieties commonly offered for sale to the Canadian trade along with a general description of such varieties according to type and colour.

TABLE 8.—CLASSIFICATION AND DESCRIPTION OF VARIETIES OF SWEDES ON SALE IN CANADA

Variety	Type				Colour								
					Skin				Flesh		Top		
					Above ground						Leaf	Stalks	
	Globe	Flat	Ovoid	Tankard	Hay's maroon	Indian red	From sorghum brown to deep livid brown	Mignonette green	Maize yellow	White	Parrot green	Parrot green tinged with Hay's maroon	Parrot green tinged with Indian red
Drummond's Improved Purple Top	x				x				x			x	
Selected Westbury	x				x				x			x	
Selected Purple Top	x				x				x			x	
Canadian Gem	x				x				x			x	
Selected Prize Elephant	x				x				x			x	
Universal	x				x				x			x	
Magnum Bonum	x				x				x			x	
Purple Top	x				x				x			x	
Sutton's Champion Purple Top	x				x				x			x	
Elephant or Monarch	x				x				x			x	
Favorite	x				x				x			x	
Bangholm	x				x				x			x	
Northern King	x				x				x			x	
Best of All	x				x				x			x	
Acquisition	x				x				x			x	
Sutton's Champion	x				x				x			x	
Hardy Purple Top	x				x				x			x	
Imperial	x				x				x			x	
New Century	x					x			x				x
Giant King	x					x			x				x
Purple Top	x					x			x				x
New Perfect	x					x			x				x
Sutton's Champion Purple Top	x					x			x				x
Bangholm	x					x			x				x
Garton's Superlative	x					x			x				x
Good Luck	x					x			x				x
Champion Purple Top	x					x			x				x
Danish Queen	x					x			x				x
Superlative	x					x			x				x
Hall's Westbury	x					x			x				x
Early Model	x					x			x				x
Improved Westbury	x					x			x				x
New Universal Purple Top	x					x			x				x
Mammoth Clyde	x					x			x				x
Northwestern	x					x			x				x
Magnum Bonum	x					x			x				x
Bangholm Purple Top	x					x			x				x
Magnificent Swede	x					x			x				x
New Balmoral	x					x			x				x
Rutabaga	x					x			x				x
Lennoxvil'e Purple Top	x					x			x				x
Hall's Westbury	x						x		x		x		
Kangaroo	x						x		x		x		
Laing's Improved Purple Top	x						x			x	x		
Derby Green Top	x						x		x		x		
Durham Bronze Top	x						x		x		x		
Hartley's Bronze Top	x						x		x		x		
Ditmars	x						x		x		x		
Ne Plus Ultra	x						x		x		x		
Perfection	x						x		x		x		
Shepherd	x						x		x		x		
Lord Derby	x						x		x		x		
Up-to-Date	x						x		x		x		
Derby Bronze Green Top	x						x		x		x		
Invicta Bronze Top	x						x		x		x		
Selected Hazard's Improved	x						x		x		x		
Gartons Viking	x						x		x		x		
Keep Well Swede	x						x		x		x		
New Empire	x						x		x		x		
Improved Yellow Swedish	x							x	x		x		
Green Top Swede	x							x	x		x		
Universal		x			x				x			x	
Hall's Westbury		x			x				x			x	
Sweet Russian		x					x		x		x		
White Swede		x						x		x	x		
Breadstone		x						x		x	x		
Elephant			x		x				x			x	
Skirvings			x		x				x			x	
Elephant or Jumbo			x		x				x			x	
Imperial			x		x				x			x	

TABLE 8.—CLASSIFICATION AND DESCRIPTION OF VARIETIES OF SWEDES ON SALE IN CANADA —*Concluded.*

Variety	Type				Colour								
					Skin				Flesh		Top		
					Above ground						Leaf	Stalks	
	Globe	Flat	Ovoid	Tankard	Hay's maroon	Indian red	From sorghum brown to deep livid brown	Mignonette green	Maize yellow	White	Parrot green	Parrot green tinged with Hay's maroon	Parrot green tinged with Indian red
Skirvings Improved			x		x				x			x	
Monarch			x		x				x			x	
Crimson King			x		x				x			x	
Improved Jumbo or Elephant			x		x				x			x	
Giant King			x		x				x			x	
Kangaroo			x				x		x		x		
Halewood's Bronze Top			x				x		x		x		
Caledonian			x				x		x		x		
Kangaroo Bronze Green Top			x				x		x		x		
Model Swede			x				x		x		x		
Superlative			x			x			x				x
New Selected Purple Top			x			x			x				x
Best of All			x			x			x				x
New Century			x			x			x				x
Prize Purple Top			x			x			x				x
Gartons Superlative			x			x			x				x
New Masterpiece			x			x			x				x
New Buffalo			x			x			x				x
Elephant or Monarch Improved				x	x				x			x	
Olsgaard Bangholm				x		x			x				x
Best of All				x		x			x				x
Selected Magnum Bonum				x		x			x				x
Bangholm Club Root Resistant				x		x			x				x
Hartley's Bronze Top				x			x		x		x		
Invicta Bronze Top				x			x		x		x		
Hazard's Improved				x			x		x		x		
Kangaroo				x			x		x		x		
Irish King				x			x		x		x		

The data presented in table 8 bear evidence to the duplication of variety names for the same root as well as the reverse practice of having different varieties sold under a common name.

CLASSIFICATION FOR TURNIPS

The turnip, more commonly known as fall turnip, does not occupy a place of prominence on many Canadian farms. It is grown to some extent for early feeding but its poor keeping qualities bar it as a desirable winter fodder.

The fall turnips sold may be divided into four general types, long, half-long, globe, and flat. The half-long type might reasonably be classified also as an intermediate type, corresponding somewhat to the similar class in mangels. Table 9 presents the results obtained from measurements made of fall turnip varieties.

TABLE 9.—FALL TURNIPS

Type	Length-Width ratio	Length-Depth ratio	Length-Distance to widest point
Long	3·63	1·49	1·56
Half-Long	2·70	1·41	1·60
Globe	1·03	1·60	1·65
Flat	0·74	1·66	1·61

In common with mangels a distinct difference is apparent between the average length-width ratios of the four types differentiated. The globe and flat types are also better suited to shallow soils than the long and half-long varieties.

CLASSIFICATION FOR CARROTS

Because of the fact that carrots are grown to only a limited extent, much fewer measurements were taken in the differentiating of types than were secured with the mangels and swedes. Three very distinct types were differentiated, however, with regard to length; namely, the long, intermediate and short. Within the long type two well-defined variations in form occur. These are the tendency to be parallel-sided and the tendency to have tapering sides. The intermediate types contained varieties which were definitely pointed at the lower extremity and others which were definitely rounded. For purposes of convenience in classification we have, therefore, differentiated five types of field carrots as outlined in table 10.

TABLE 10.—CARROTS—AVERAGE OF ALL MEASUREMENTS

Type	Length-Width		Length-Depth		Length-Distance to widest point	
	Range	Ratio	Range	Ratio	Range	Ratio
Long, parallel sided	6·0 9·0	7·259	1·1 2·5	1·606		
Long, tapering	4·5 7·5	5·542	1·0 1·2	1·045	1·0 1·2	1·069
Intermediate, pointed	2·3 3·8	3·026	1·1 1·7	1·276	1·0 1·4	1·140
Intermediate, round-pointed	2·0 3·5	2·783	1·0 1·6	1·188	1·1 1·4	1·176
Short	1·1 1·9	1·364	1·0 1·4	1·180	1·0 1·4	1·155

Each of the types defined in this table has a characteristic length-width ratio. Here again we find an adaptation of type to soil, in that the long varieties give better results on the deeper soils and the short or intermediate types on the more shallow soils.

Among the field roots commonly grown, carrots are the most firmly anchored in the soil. In the case of the deeper rooted varieties it is almost impossible to remove them from the soil without loosening them either by a plough or digging-fork. In an open-textured soil some of the intermediate varieties can be pulled by hand, while the short types, particularly of the Oxheart class, can usually be pulled without any previous loosening.

The tendency to coin new names for existing varieties is also exemplified by reference to table 11.

In table 11 are presented the results of our investigations with regard to the most commonly sold varieties of field carrots. It is interesting to note that there are ten different lots of white intermediate carrots sold under slightly varying trade names but which are essentially the same with regard to the various morphological characteristics listed.

TABLE 11.—CLASSIFICATION OF VARIETIES OF CARROTS COMMONLY SOLD IN CANADA

Variety	Type							Colour									
	Long			Intermediate		Short		Skin						Flesh		
								Aboveground			Below ground					
	Round shoulder, parallel sided	Round shoulder converging from top	Round shoulder converging both ways	Square shoulder converging from top	Square shoulder round tip	Round tip	Square shoulder short broad	Vinaceous brown	Vinaceous brown and oil yellow	Vinaceous brown and bitter-sweet orange	White	Buff yellow	Bittersweet orange	White	Apricot yellow	Bittersweet orange
White Belgian	x	....	....	....	....	....	....	x	....	....	x	....	....	x	....	....
Yellow Belgian	x	....	....	....	....	....	....	....	x	....	....	x	....	....	x	....
Champion	x	....	....	....	....	....	....	x	....	....	....	....	x	....	....	x
James Long Hinderupgaard V	....	x	....	....	....	....	....	....	....	x	....	....	x	....	....	x
Long Orange	....	x	....	....	....	....	....	x	....	....	....	....	x	....	....	x
New Yellow Intermediate	....	....	x	....	....	....	....	....	x	....	....	x	....	....	x	....
Large White Belgian	....	....	x	....	....	....	....	x	....	....	x	....	....	x	....	....
Long Orange Belgian	....	....	x	....	....	....	....	....	x	....	....	x	....	....	x	....
White Belgian 9008	....	....	x	....	....	....	....	x	....	....	x	....	....	x	....	....
White Belgian	....	....	x	....	....	....	....	....	x	....	x	....	....	x	....	....
Danish Champion	....	....	....	x	....	....	....	x	....	....	....	x	....	....	x	....
Champion 1535	....	....	....	x	....	....	....	....	x	....	....	x	....	....	x	....
Ontario Champion	....	....	....	x	....	....	....	....	x	....	....	x	....	....	x	....
Yellow Belgian	....	....	....	x	....	....	....	....	x	....	....	x	....	....	x	....
White Intermediate	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Mammoth White Intermediate	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Mammoth Intermediate White	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Improved Intermediate White	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Half Long White	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Mammoth Half Long White	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Mammoth Short White	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Improved Short White	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Large White Vosges	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Improved White Vosges	....	....	....	x	....	....	....	x	....	....	x	....	....	x	....	....
Improved Danvers	....	....	....	....	x	....	....	....	....	x	....	....	x	....	....	x
Improved Danvers Half Long	....	....	....	....	x	....	....	....	....	x	....	....	x	....	....	x
Oxheart	....	....	....	....	....	....	x	....	....	x	....	....	x	....	....	x

FACTORS AFFECTING YIELD

In our consideration of the factors affecting yield, reference will be made almost entirely to the different factors in so far as their affect on the mangel crop is concerned. The extreme variations in type which occur in the mangel renders it particularly suitable for ecological studies.

The first phase of this subject that we wish to present is the relative yields of the different types as differentiated in the mechanical classification presented. In compiling the data found in table 12 only roots which our records showed to be true to type were included. As a great many more varieties belonging to the long, intermediate, and globe types were tested than of the other three types, it was thought advisable to limit our comparison to an average of the five highest-yielding varieties in each type. This average was based on measurements secured over a period of three years and should be fairly representative of the relationship existing between the types in as far as yield is concerned.

The soil on which the mangel variety test was carried out was reasonably rich and friable enough to allow the normal development of all the types.

TABLE 12.—YIELD PER ACRE OF THE FIVE HIGHEST-YIELDING VARIETIES OF THE VARIOUS MANGEL TYPES

Type	Year	As harvested				Dry matter	
		Roots		Tops		Roots	
		tons	lb.	tons	lb.	tons	lb.
Long	1920	49	356	5	1,299	4	1,247
	1921	25	1,035	3	1,097	2	1,746
	1922	33	1,734	2	1,685	4	1,156
Average	....	36	375	4	27	4	50
Half-Long	1920	48	604	5	369	4	1,248
	1921	26	778	2	1,255	2	1,411
	1922	35	1,988	2	1,509	4	1,508
Average	....	36	1,790	3	1,048	4	56
Intermediate	1920	48	1,887	5	945	4	1,080
	1921	29	1,503	3	120	2	1,860
	1922	40	560	3	749	5	188
Average	....	39	1,317	3	1,938	4	376
Globe	1920	45	753	2	118	3	390
	1921	26	633	1	1,289	2	338
	1922	29	675	1	647	3	713
Average	....	33	1,354	1	1,351	2	1,814
Tankard	1920	41	1,990	3	77	3	804
	1921	25	1,039	1	1,607	2	449
	1922	37	1,675	2	1,017	4	10
Average	....	35	235	2	900	3	421

The data presented in table 12 indicate little difference between the yield of dry matter secured from the long and half-long types. The intermediate types have averaged a little higher in their total yield of both green and dry matter than any of the other types recorded. Unfortunately too few individuals of the ovoid type were available to compute satisfactory averages; as a consequence this type had to be omitted from the investigation. It will be noted that while the globe and tankard types have given almost as much green material per acre as the remaining types, the amount of dry matter secured from them is very appreciably less. This of course indicates a lower percentage of dry matter.

In order that we may get a clearer understanding of the question just raised as to the relationship between type and dry-matter content, a graphic representation is included of the relative amounts of dry matter for the different types during the years 1920, 1921, and 1922.

With the exception of the year 1920, the long types have given us the highest average dry matter, the half-long the second highest, the intermediate next, followed by the tankard and globe types.

That much the same relationship between types and total yield of dry matter is found also in the case of field carrots is illustrated by reference to table 13.

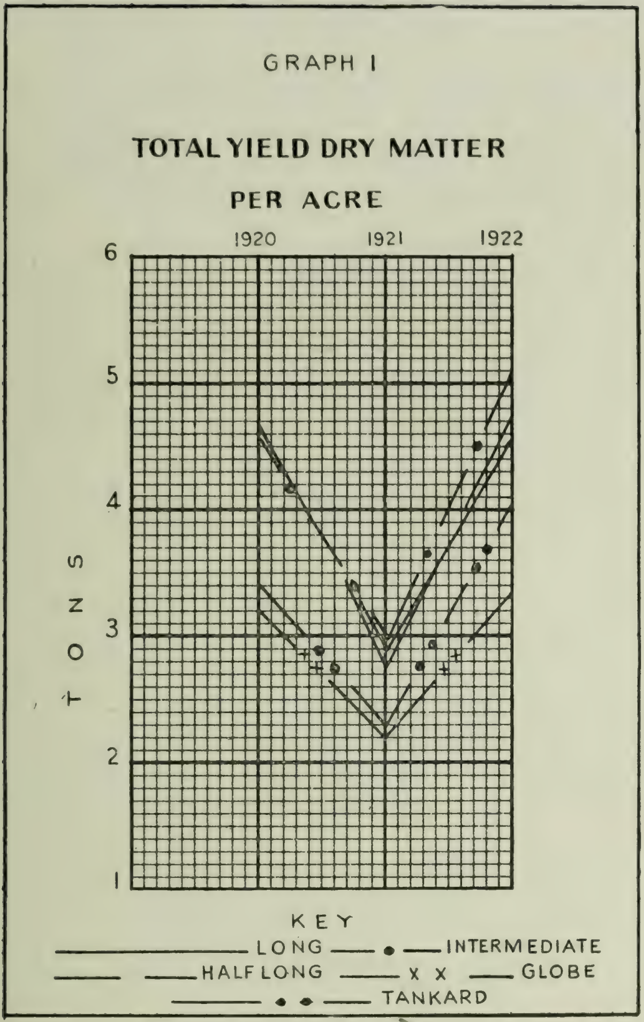


TABLE 13.—THREE-YEAR AVERAGE OF THE FIVE HIGHEST-YIELDING VARIETIES OF CARROTS (1920-21-22)

Long				Intermediate				Short			
Yield per acre		Dry matter per acre		Yield per acre		Dry matter per acre		Yield per acre		Dry matter per acre	
tons	lb.	tons	lb.	tons	lb.	tons	lb.	tons	lb.	tons	lb.
25	1,279	3	133	32	962	3	1,303	30	696	3	1,517

There is not the same proportion of variation as illustrated in the case of different mangel types, when the total dry matter is used as the basis of comparison. While the intermediate types have given the highest yield of roots as harvested, when this yield has been reduced to a dry-matter basis the short types have given a small increase in total dry matter. It is doubtful, however,

if this increase can be considered significant. The long varieties under our conditions at the Central Experimental Farm have not given as satisfactory yields of either harvested roots or dry matter per acre as have the other two types.

Certain well defined morphological characteristics and growth habits within each type appear to be definitely associated with the percentage of dry matter. One of these is the relationship between average percentage of top and the accompanying dry matter. Table 12 records in figures the total weights of tops secured from the different types. The same data is presented on a percentage basis in table 14.

TABLE 14.—PERCENTAGE OF TOPS AND DRY MATTER OF THE VARIOUS MANGEL TYPES

Year	Long		Half-Long		Intermediate		Globe		Tankard	
	Tops in per cent of roots	Per cent dry matter	Tops in per cent of roots	Per cent dry matter	Tops in per cent of roots	Per cent dry matter	Tops in per cent of roots	Per cent dry matter	Tops in per cent of roots	Per cent dry matter
1920	11·46	9·44	10·55	9·69	11·45	9·47	4·53	7·02	7·31	8·19
1921	13·90	11·28	9·99	10·26	10·36	9·87	6·25	8·24	7·20	8·78
1922	8·41	13·50	7·70	13·25	8·38	12·65	4·45	11·49	6·75	11·28
Average	11·26	11·41	9·41	11·07	10·06	10·66	5·08	8·92	7·09	9·42

In table 14 it will be noticed that there is a definite correlation between the percentage of top possessed by any type of roots and the accompanying percentage of dry matter; thus the long types which show the highest percentage of top in proportion to root have at the same time the largest percentage of dry matter. With the exception of a slight deviation found in the case of the half-long, the other types all show a reduction in the percentage of top to be accompanied by a reduction in the percentage of dry matter. The significance of this fact in the breeding of improved strains will be discussed later.

There is a decided variation not only in the total yield but in the percentage of dry matter obtained from field roots in different seasons. It is somewhat difficult to advance a theory that would account for all of the fluctuations which occur; but an examination of the accompanying graphs may throw some light on at least a few climatic factors affecting yield and percentage of dry matter.

The graphs presented give in turn, for the years 1920, '21, and '22, the total dry matter per acre, the percentage of dry matter, and the percentage of top. In conjunction with these there is presented for the months of May, June, July, August, September, and October, the total number of hours of sunshine per month, the mean temperature and the precipitation in inches.

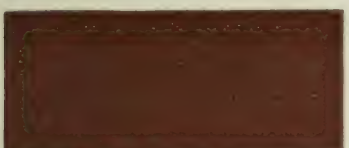
An examination of the data presented brings out the fact that there appears to be a greater correlation between precipitation, especially during the early part of the growing season, and yield of dry matter, than exists in the case of either the mean temperatures or the duration of the sunshine. The comparatively low total dry-matter yield for the year 1921 is accompanied by a low average precipitation for the growing season. It is true that in the month of June, 1921, the precipitation was somewhat higher than in the corresponding month in the year 1922. Later precipitation in the year 1921, however, was low enough to more than offset the somewhat increased amount it received over 1920 in the one month. Coupled with this low precipitation in the year 1921 we find the highest mean temperature, which occurrence would result in excessive evaporation with a consequent exaggeration of drought.

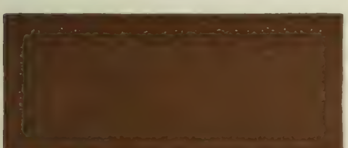
PLATE I

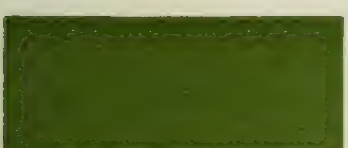

Maroon
Old Rose
Hay's Maroon
Flame Scarlet
Indian Red
Japan Rose
Oxblood Red
Cadmium Orange
Carmine
Bittersweet Orange
Nopal Red
Pale Smoke Gray
Begonia Rose
White

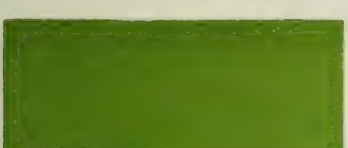
PLATE II


Deep Livid Brown


Vinaceous Brown


Sorghum Brown


Forest Green


Parrot Green


Mignonette Green


Lime Green


Oil Yellow

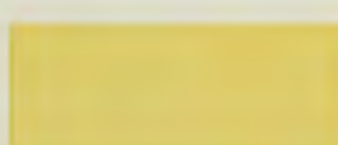

Olive Yellow

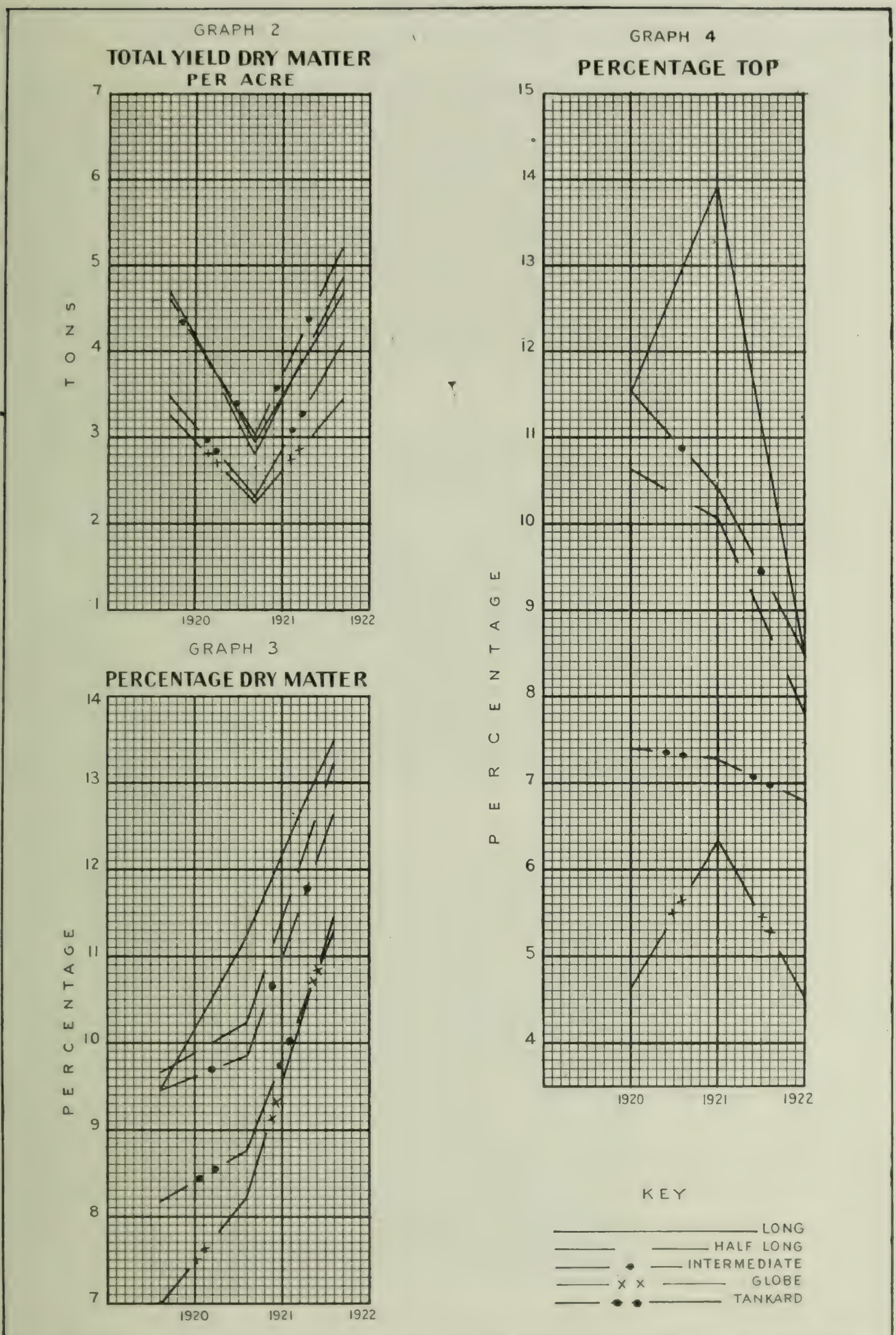

Olive Ocher

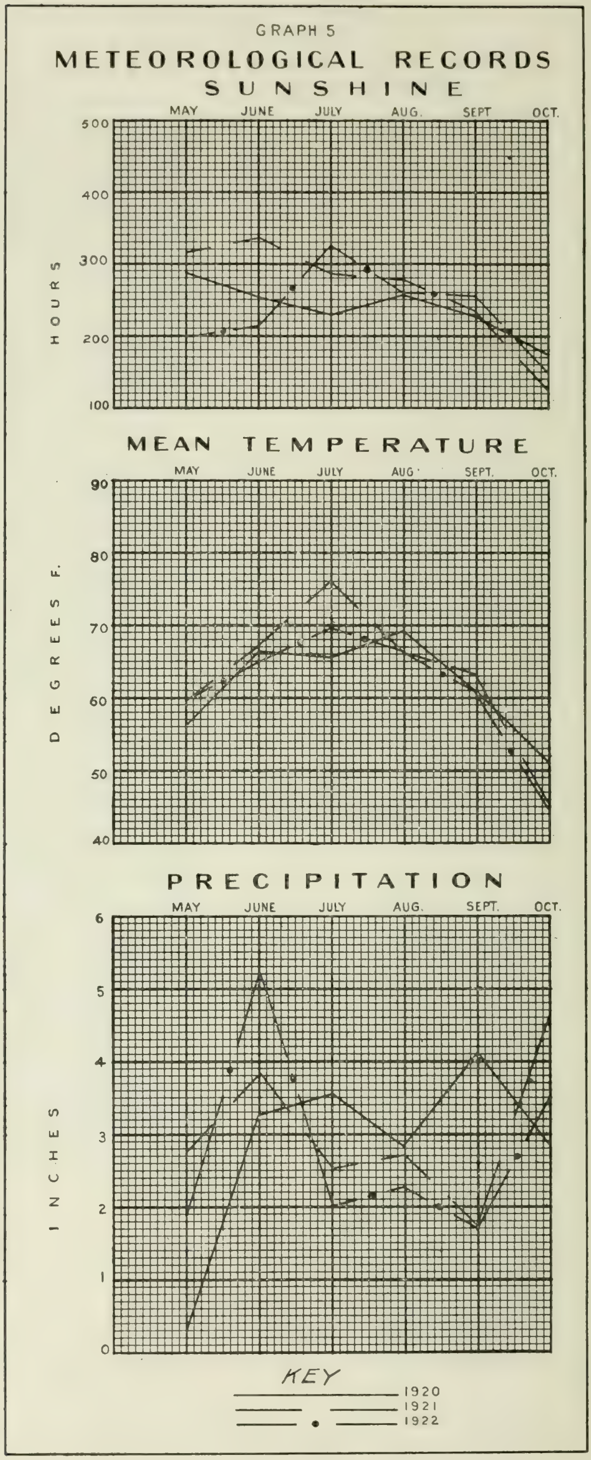

Wax Yellow


Apricot Yellow


Buff Yellow


Maize Yellow


GRAPH 2
TOTAL YIELD DRY MATTER PER ACRE
TONS
7
6
5
4
3
2
1
1920
1921
1922
GRAPH 3
PERCENTAGE DRY MATTER
PERCENTAGE
14
13
12
11
10
9
8
7
1920
1921
1922
GRAPH 4
PERCENTAGE TOP
PERCENTAGE
15
14
13
12
11
10
9
8
7
6
5
4
1920
1921
1922
KEY
LONG
HALF LONG
INTERMEDIATE
GLOBE
TANKARD


GRAPH 5
METEOROLOGICAL RECORDS
SUNSHINE
MAY JUNE JULY AUG. SEPT OCT.
500 400 300 200 100
HOURS
MEAN TEMPERATURE
MAY JUNE JULY AUG. SEPT. OCT.
90 80 70 60 50 40
DEGREES F.
PRECIPITATION
MAY JUNE JULY AUG. SEPT. OCT.
6 5 4 3 2 1 0
INCHES
KEY
1920
1921
1922

In so far as the percentage of dry matter is concerned, there appears to be a steady increase through the years 1920, '21, and '22. It would appear as if the lower initial precipitation in 1920 in conjunction with the higher summer and fall precipitation resulted in a retarded early summer growth and a speeding up of the fall growth. This is what our records actually indicate as having happened and it would seem as if it has been associated with a lower percentage of dry matter in all of the types tested. As far as the extremes in types are concerned, it appears as if the climatic conditions responsible for the larger total yield were also responsible for a decreased percentage of dry matter.

BREEDING

Field roots as a whole lend themselves very definitely to improvement by breeding. This is largely because of the fact that they are for the most part open-fertilized and consequently impure in the unselected state.

The early efforts towards improving field roots consisted in the selection of desirable roots from the harvested crop and the use of these for the production of seed for succeeding generations. The continued application of this method of improvement has resulted in material progress but the improvement has not been as rapid or as positive in its results as might be desired.

In a country where as wide variations occur in soil and climate as are found in Canada, the type of field root which would appear to be the most promising for improvement is the intermediate, which might include as well the larger of the ovoid types and the shorter of the half-long types. Our field tests to date have indicated that these intermediate types have given the highest total yield of dry matter per acre. As the name would indicate they are also more suitable to the general run of soils than are the deeper-rooted long types or the very shallow-rooted tankard or globe types. Under these conditions it is not surprising that the great majority of the strains being developed by Canadian plant-breeders are of the ovoid, intermediate and half-long types.

It would appear as if most plant-breeders, in undertaking the improvement of field roots, have given consideration mainly to the tap root itself, selecting largely on the basis of shape, colour and dry matter.

Anyone who has had the opportunity of observing the first year's growth of field roots, particularly of the mangel, cannot help but be impressed by the large amount of variation occurring in the foliage of this plant. That the amount of foliage present is quite definitely correlated with the dry-matter content of the root is evidenced by the data presented in table 14. The proportion of foliage possessed by any root has in addition an indirect bearing on its adaptability. In certain sections of the country, or in unusual seasons, in any section, early frosts cause considerable damage to the growing crop. A root variety with a large top seems to be able to withstand such a condition much better than the smaller topped sorts.

The chief objection to the selection of the extremes in heavy top is the demonstrated correlation between this characteristic and the tendency to be deep rooted and hence difficult to extract. There also appears to be a greater tendency for the deep-rooted segregates of any variety to be more prongy than the shallower-rooted individuals.

Some interesting investigations have been carried out in Denmark, substantiating our findings in this connection. Various lots of intermediate mangels were selected on the basis of the relative proportion of top to root. Their results can be best demonstrated by the inclusion of a drawing and table from the publication by Professor E. Lindhard and Assistant J. Chr. Lunden.

Figure No. 8 shows five types of the intermediate mangel grown in Denmark. The ground-line indicates the various habits of growth with regard to the proportion of the root above and below ground. The proportion of top in comparison to the size of the root is also indicated. It will be observed that there is a definite correlation between the proportion of the root growing in the ground and the amount of top which the strain possesses. The absolute proportion of top to root and also the percentage dry matter is tabulated in table 15.

TABLE 15.—INTERMEDIATE MANGELS—PROPORTION OF TOP TO ROOT AND PERCENTAGE OF DRY MATTER

Variety	Kilograms per ha. (2·47 acres)		Per cent dry matter in root
	Root	Top	
Naesgaard	63,900	23,500	13·6
Sludstrup	69,000	21,400	12·7
Rosted	72,900	18,400	12·5
Ferritslev	75,000	17,100	12·1
Taaroje	77,600	15,500	11·3

The results of this investigation indicate that even within a common type there is a definite correlation in the proportion of the root in the ground, the size of the top and the percentage of dry matter. The strain which has the lowest total harvested yield of root has the largest proportion of top and the highest percentage of dry matter, whereas the strain which gave the highest

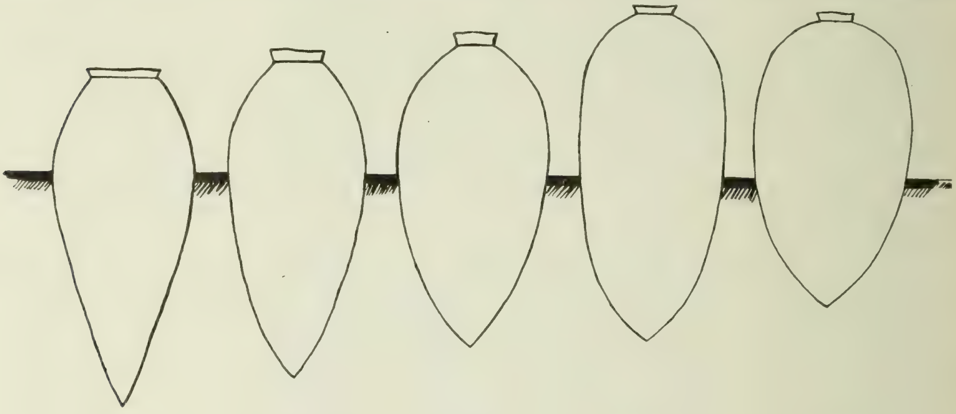


FIG. 8.—Five types of intermediate mangel grown in Denmark.

yield of root possesses the smallest amount of top and the lowest percentage of dry matter. An interesting point in connection with this table is that the Sludstrup and Rosted types which are about midway between the extremes with regard to top and depth in ground have yielded the highest total dry matter per acre. It would seem, therefore, that even within the variates of a type the intermediate members would make the most profitable selections.

In the instance of the tap root of the field carrot, certain structural relationships have an important bearing on the nutritive value of the resulting root. A transverse section of a carrot will show two well defined areas, a thick outer layer commonly called the bark and a central portion usually of different colour and which is commonly termed the core. It has been quite definitely established that the bark contains a higher percentage of sugar and other

nutrient materials than is found in the core. Breeders who realize this fact endeavour to select roots with the highest possible proportion of bark in order that the total feeding value of the root may be increased.

The data that have been presented indicate that it is worth while taking into consideration more than the tap root itself when selecting for improved types of field roots.

During the summer of 1926 the staff of the Forage Plant Division made an extensive collection of leaf types existing within strains and varieties of mangels on our test grounds. A number of drawings are included (figs. 9-13) which indicate the extent of variation which occurs in the structural characteristics of the mangel leaf.

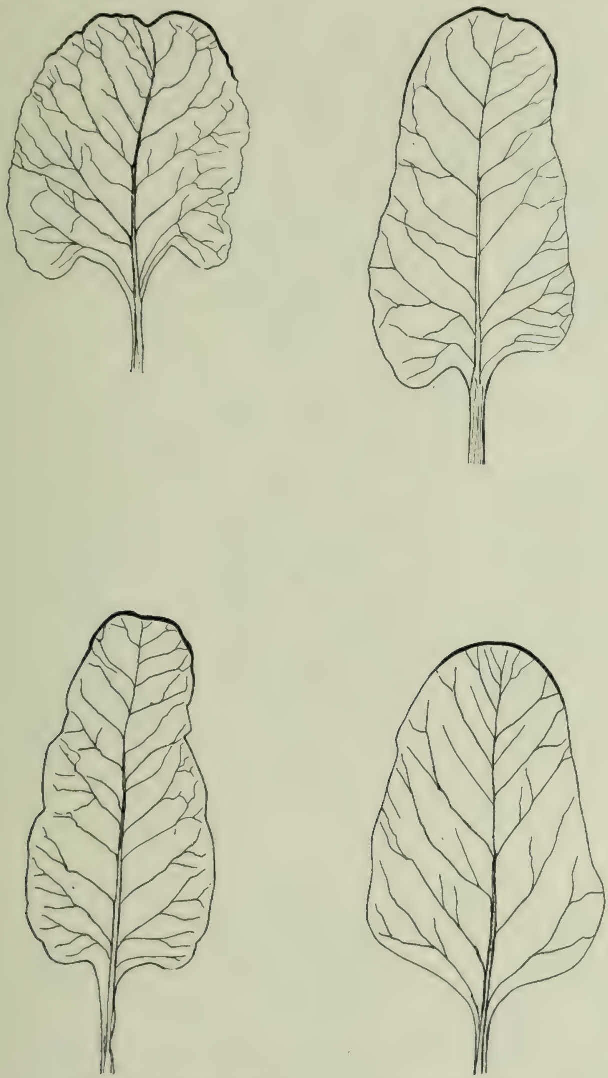


FIG. 9.—Mangel leaf types. Variations in tip.

For the purpose of comparison the leaves are grouped to indicate the variations in tip, base, venation, margin and general shape. It seems quite possible that environomental conditions may influence the degree of expression of the variations illustrated, but they appear to be fairly constant within the members of the purest strains.

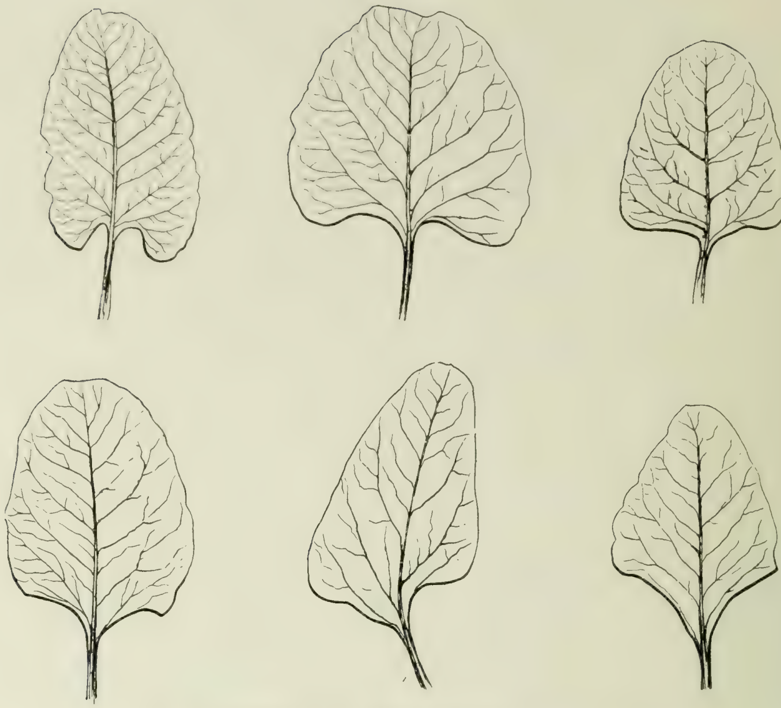


FIG. 10.—Mangel leaf types. Variations in base.

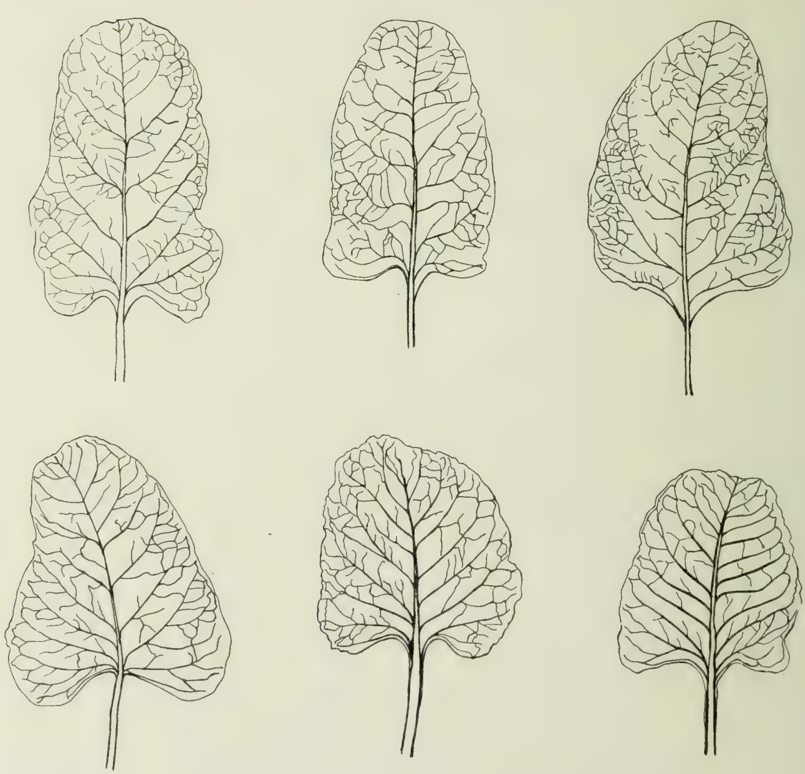


FIG. 11.—Mangel leaf types. Venation.

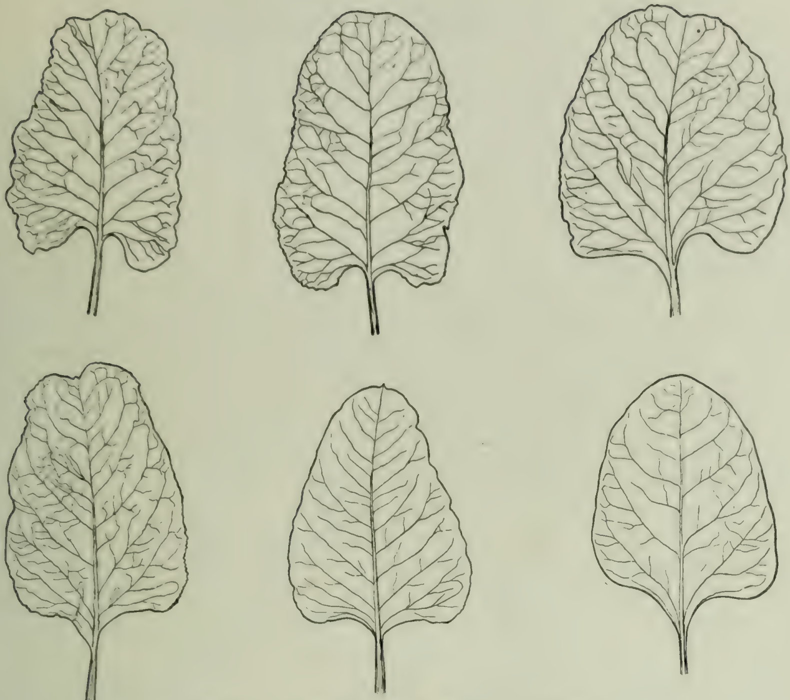


FIG. 12.— Mangel leaf types. Margins.

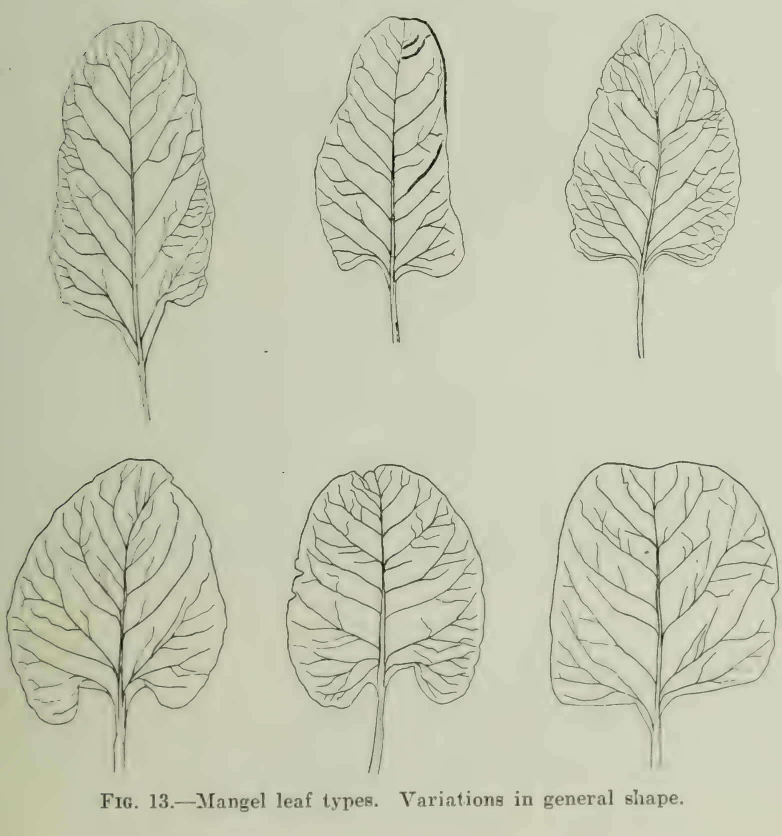


FIG. 13.—Mangel leaf types. Variations in general shape.

THE ISOLATION OF FIELD ROOTS

The propagation of pure stocks of either varieties or strains of field roots can be accomplished only by employing some method of isolation. The necessity for such isolation arises because of the fact that the commonly grown kinds of field roots cross readily with closely allied plants of the same and in some cases, different species.

The method employed for effective isolation will depend largely on the instrumentality by which cross-fertilization is brought about. The two most common carriers of pollen are wind and numerous species of insects. A discussion of the fertilization of mangels, swedes and carrots is included here to afford a better understanding of the reason for the suggested methods of isolation. The real point at issue with regard to these crops is whether they are cross-pollinated by wind or insects.

In the case of mangels some authorities are of the opinion that wind plays little part in cross-pollination. There seems to be several well grounded reasons for this opinion. In the first place the small insignificant closely-set clusters of flowers are not very accessible to the influence of wind. The pollen is also not easily dispersed. Furthermore the anthers do not dehisce all at once, practically all stages of flower development being found on the same plant. The flower itself does not open suddenly as is the case in most plants which are known to be wind-pollinated, nor does the flower possess the slender parts peculiar to such plants. On the whole the odds would seem very much against wind-pollination. In conjunction with the evidence against wind-pollination we find that insects of many kinds visit the flower. These belong largely to the smaller bugs, aphids, and flies.

In spite of the arguments presented in favour of insect-pollination it would appear as if wind also must play no small part in the dissemination of the pollen from the mangel flower. One has only to walk through a mangel patch during the flowering season to become thoroughly covered with pollen no matter how carefully contact with the surrounding plants is avoided. This being the case, wind-pollination must play at least some part in the intercrossing of varieties and strains.

Swedes are claimed to be largely cross-pollinated under natural conditions. The structure of the anthers and stigma are such that insects visiting the flowers would be very likely to come in contact with the pollen of the flower visited. Provision is also made for self-fertilization as the anthers in the later stages of development arrange themselves in such a manner that self-pollination could readily be carried out. It also seems possible for wind to play a part in the cross-pollination of the flowers of the swede although the odds are in favour of insect pollination. The arrangement of the floral parts and the conspicuousness of the flowers suggest the latter method. The insects most commonly found visiting the flower of the swedes are the honey-bee and various wild species of bees, the white cabbage butterfly, aphides and to a lesser extent a number of other insects.

The carrot is reported to be almost entirely cross-pollinated by insects. Certain well-defined peculiarities of the flowering parts lend themselves to this theory. The umbrella-like attitude adopted by the flower-cluster renders it sufficiently distinctive to attract insects. In addition to this shape, the flower possesses an aromatic odour and contains a supply of nectar. The visits of more different kinds of insects to the flower of the carrot are reported than with either the mangel or the swede. This is borne out by the fact that the following families are each represented by a number of species: Coleoptera, Hymenoptera, Diptera, Hemiptera, Lepidoptera, Neuroptera. Our own experiences with the carrot have not led us to form a definite opinion as to whether or not it is possible for wind to play a part in the dissemination of pollen.

METHODS OF ISOLATION

Assuming that both wind and insects play a part in the cross-fertilization of mangels and swedes any method of isolation adopted must guard against contamination from either of these sources. Although wind-pollination is doubtful in the case of the carrot we have placed it in the same category as the other two types of plants in our method of handling this crop during the flowering season.

The following two methods of isolation are commonly employed with the root crops under discussion:—

1. Isolation by Distance.—Where wind-pollination alone is to be guarded against, isolation by a distance of one-quarter of a mile is considered sufficient for most plants. If natural barriers can be utilized in the intervening spaces, shorter distances will suffice. When in addition to wind, insects also function as carriers of pollen the distance necessary to avoid contamination must be greatly increased. The exact distance that would afford safety will depend on the normal range of flight of the various insect visitors of the plants concerned.

We are not in a position to give definite evidence regarding the minimum distance necessary for immunity from cross-fertilization, but we have records of contamination at distances of around five hundred yards. The Svalof Plant Breeding Station recommends a distance of not less than one thousand metres where the isolation of field roots by distance is desired.

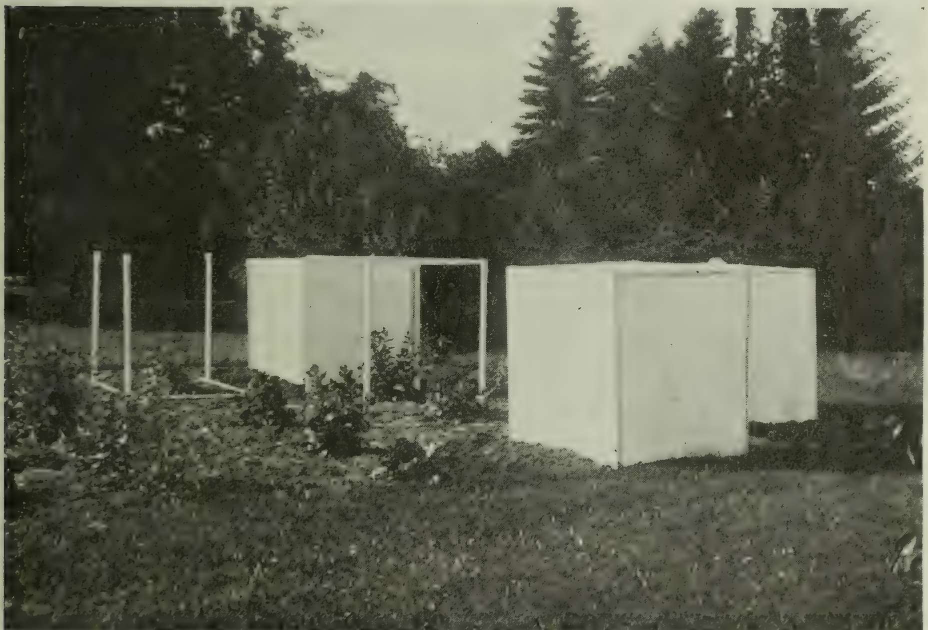


Fig. 14.—Isolation cages for field roots.

In our breeding work we have at times followed the practice of having different men connected with the Division take home a single root and plant it in their gardens. Care was taken to see that men living at all close to each other were not furnished with roots belonging to the same family. The seed-setting on roots thus isolated was in most cases very satisfactory and the isolation appeared to be all that was necessary.

2. Isolation by Covering.—Where a number of strains of the same type of root are being worked with, the use of some protective covering is by far the most common method of isolation followed. A number of different methods of utilizing the covering material are in common use as well as a fairly wide variation in the kinds of material employed for this purpose. Some plant-breeders simply enclose a portion of the plant to be isolated, others cover the entire plant, while a further practice consists of putting a number of plants of the same strain under a common cover. Each method appears to have its own particular merits.

At the Central Experimental Farm we have employed the method of covering individual plants with a cotton-covered cage of sufficient size to allow the normal development of the plant. As an additional safety factor a double covering has been placed around three sides of the cage, the side left with the single layer of material being that opposite to the direction of the prevailing winds. Figure 14 will illustrate the type of cage used for the isolation of all types of roots with which we have been working.

The seed-setting of caged plants, no matter what type of covering is used, is almost invariably much lighter than that secured from plants allowed to set seed in the open, although isolated by a sufficient distance to prevent any cross-fertilization. A reason for this light seed-setting can be found in the abnormal conditions under which the plant is placed by reason of the covering. The temperature within such cages is very much in excess of that in the open. The humidity also is modified and the action of the sunlight interfered with. In spite of these unfavourable environmental conditions, it is usually possible to obtain sufficient seed for improvement purposes.

SEED-RAISING

Previous to the Great War there existed a conception that field root seed grown in Canada was not capable of producing as good crops as seed of the same varieties imported from Europe. Until that time the amount of field root seed raised in Canada was negligible, the bulk of seed used being imported from Europe, supplemented by small quantities from the United States. During the war, field root seed-raising received considerable impetus in Canada due to the fact that such seed was not available for import from Europe. It was a case of growing seed in Canada or cutting down the acreage of the crops. The Experimental Farms, both provincial and federal, and many private growers, took up field root seed-raising with very favourable results.

The outstanding accomplishment was to prove conclusively that field root seed can be raised in Canada and that the crops produced from such seed were equal, and in many cases superior, both in yield and quality, to crops of the same varieties grown from imported seed. Not only during war years, when the best seed from Europe was probably not obtainable, but since imports have again become available, Canadian-grown seed has proven entirely satisfactory both as to yield and quality of crops produced. Extensive variety tests conducted on Experimental Farms and Stations with Canadian and imported varieties of mangels, swedes, field carrots, and sugar beets have given ample proof of the continued stability of the Canadian-grown seed.

At the present time root seed is being raised successfully in Canada: swedes in sections of the Maritime Provinces; mangels, sugar beets, and field carrots in Ontario and British Columbia. In the latter province, in those sections where severe winter conditions do not prevail, many growers are producing seed of excellent strains of field roots at a cost which shows good profit.

FIG. 15.—Mangel and carrot seed crop. (Ottawa, Ont.)

FIG. 16.—Mangel seed crop (Experimental Station, Summerland, B.C.).

The growers of field root seed can be divided into two main classes: those who are growing for home use and those who are growing seed on a commercial scale.

Forty to one hundred roots will provide sufficient seed for the average farmer and no special obstacle stands in the way of the production of field root seed for home use.

For the commercial grower, some special machines are required and as roots for seed require use of land for two years before returns can be obtained, growers should go carefully into possible market conditions before attempting to raise such seed in large quantities. Once a grower establishes a market and continues to produce seed of a good variety he should have no trouble in disposing of increased quantities of seed. It is advisable that the commercial grower start on a small scale with a recognized and improved selection and establish the fact that he is working intelligently on the improvement of the variety selected before growing large acreages for seed production. Further, no grower should attempt to grow more than one variety at the same time. Mangel and sugar beet varieties cross very readily, as do also varieties of swedes. Under ordinary conditions the only safe way to prevent inter-crossing is to grow not more than one variety of each class.

Soil for seed roots must be in good mechanical condition, early and warm. Stiff clay and land which is late in warming up in the spring is not suitable for seed-raising, neither can seed-raising be carried on successfully in competition with weeds. Field roots can be utilized as a cleaning crop on weedy land, but the nature of growth of seed plants renders any but early horse and hand cultivation impossible. Seed roots should only be set out on land as free from weeds as possible. The earlier seed roots can be set out in the spring the greater will be the chance of high yields. For this reason fall ploughing and preparation of soil is advisable so that no avoidable delay may prevent early planting.

Results where manure and fertilizers were used alone and in combination to stimulate seed production are shown in table 16.

TABLE 16.—MANGEL SEED—FERTILIZER EXPERIMENTS

Plot	Commercial fertilizers per acre	Total	Cost	No manure		12½ tons manure at $1 per ton				25 tons manure at $1 per ton			
				Yield	Value of seed	Yield	In-creased cost	Value of seed	Net increase in profit	Yield	In-creased cost	Value of seed	Net increase in profit
		lb.	$ cts.	lb.	$ cts.	lb.	$ cts.	$ cts.	$ cts.	lb.	$ cts.	$ cts.	$ cts.
1	300 pounds nitrate of soda 240 " muriate of potash 800 " superphosphate	1,340	28 79	1,260	378 00	1,420	12 50	426 00	35 50	1,480	25 00	444 00	41 00
2	150 " nitrate of soda 240 " muriate of potash 800 " superphosphate	1,190	23 27	1,240	372 00	1,390	12 50	417 00	32 50	1,500	25 00	450 00	53 00
3	300 " nitrate of soda 240 " muriate of potash 400 " superphosphate	940	22 79	1,050	315 00	1,020	12 50	306 00	−21 50	1,400	25 00	420 00	80 00
4	150 " nitrate of soda 240 " muriate of potash 400 " superphosphate	790	17 27	960	288 00	990	12 50	297 00	− 3 50	1,160	25 00	348 00	35 00
5	No commercial fertilizer	....	....	760	228 00	900	12 50	270 00	29 50	980	25 00	294 00	41 00
6	300 pounds nitrate of soda 120 " muriate of potash 800 " superphosphate	....	25 91	1,190	357 00	1,110	12 50	333 00	−36 50	1,480	25 00	444 00	62 00
7	150 " nitrate of soda 120 " muriate of potash 800 " superphosphate	....	20 39	1,280	384 00	1,460	12 50	438 00	41 50	1,400	25 00	420 00	11 00
8	300 " nitrate of soda 120 " muriate of potash 400 " superphosphate	....	19 91	1,000	300 00	1,200	12 50	360 00	47 50	1,260	25 00	378 00	53 00
9	150 " nitrate of soda 120 " muriate of potash 400 " superphosphate	....	14 39	880	264 00	910	12 50	273 00	− 3 50	960	25 00	288 00	− 1 00
10	No commercial fertilizer	....	....	710	213 00	880	12 50	264 00	38 50	900	25 00	270 00	32 00

1926 Prices

Nitrate of soda	$73 50 per ton
Muriate of potash	48 00 "
Superphosphate	30 00 "
Manure	2 00 " (50 per cent chargeable to crop)
Seed	30 per lb.

To produce profitable yields, seed roots must have readily available plant food, and although a good application of manure will give fair results, best results are obtained where commercial fertilizers are used to supplement the application of barnyard manure.

Seed can be grown from either mature roots or from small immature roots known as stecklings. The advantages of using the latter are that seed for their production can be planted later in the season, more roots can be grown per acre and due to the small size they are easier to handle and take up less storage room than mature roots. They do not, however, allow for intelligent selection, so that the use of stecklings should be limited only to the growing of commercial seed crops from previously selected seed. Other conditions being equal, stecklings will not produce as much seed as mature roots. This has been repeatedly proven, and typical results are shown in table 17, which deals with seed yields from small and mature roots, where fertilizer applications and distances between roots varied. It will be noted that in all cases the yields from mature roots are substantially greater than from stecklings.

TABLE 17.—STECKLINGS vs. MATURE MANGELS FOR SEED PRODUCTION—SEED YIELDS PER ACRE

—	Stecklings		Mature Roots	
	Plants 3′ x 3′	Plants 3′ x 1½′	Plants 3′ x 3′	Plants 3′ x 1½′
	lb.	lb.	lb.	lb.
Commercial fertilizer	1,225	1,676	2,187	2,689
Commercial fertilizer plus 10 tons manure	1,296	2,264	2,385	3,048
Commercial fertilizer plus 20 tons manure	1,744	2,604	2,476	3,672

In a similar experiment 1,800 roots 4 to 5 inches in diameter were selected and tested against roots with a diameter of 2 to 2½ inches. These were planted in rows 3 feet apart, with 2 feet between plants in the row. A 10 per cent better stand was obtained with the larger roots, as a considerable number of the stecklings merely increased in size but did not send out seed-stalks. The crop from the mature roots was also earlier and the stand was much evener than from the stecklings. The mature roots yielded a total of 2,105 pounds of marketable seed while the stecklings only yielded 1,468 pounds.

If stecklings are used for commercial seed-raising, the grower must produce sufficient mature roots each year to carry on a selection and produce sufficient seed from these roots to grow stecklings and also mature roots for further selection.

Roots for seed-raising must be handled with care, particular pains being taken that no damage is done in harvesting and storing. For seed-raising the leaves should not be twisted off but cut two or three inches from the top of the root. No trimming of roots is advisable where such roots are to be used for seed production. A critical examination should be made at harvest time and all damaged, misshapen, prongy and off-type roots discarded.

Many methods of holding roots over winter have been tried in Canada, but in all but a few sections of British Columbia some handling has been found necessary.

Winter storage has been tried extensively along the following lines:

1. Leaving the roots in the ground where grown and thinning to the desired distance in the spring. This method is possible for some parts of British Columbia but is not recommended because it does not permit satisfactory selection of the roots.

2. Pulling and topping in the regular way and then replanting in trenches where the seed is to be produced. This method allows for selection, but except where winter conditions are not severe, it has not proven successful. Attempts to protect the plants with straw or manure have repeatedly resulted in small percentages of good roots in the spring. Before such a method is attempted on a large scale trials should be made with small lots. In parts of the Maritime Provinces, swedes are kept over by layering, and similar practices have been successful with mangels and carrots in parts of British Columbia.

3. Storing in root-cellars.

4. Storing in pits.

Providing cellars and pits are properly constructed and handled they offer by far the best means of winter storage for average Canadian conditions. Root-cellars and their construction are dealt with fully in Pamphlet No. 10, New Series (Root and Storage Cellars). Such cellars have the advantage of permanence but are not as cheap storage as that provided by pits. Where many and extreme changes of temperature occur during normal winters, root-cellars are to be preferred. Where, as in Ontario, winter temperatures are more constant, root-pits provide a safe and comparatively cheap form of storage.

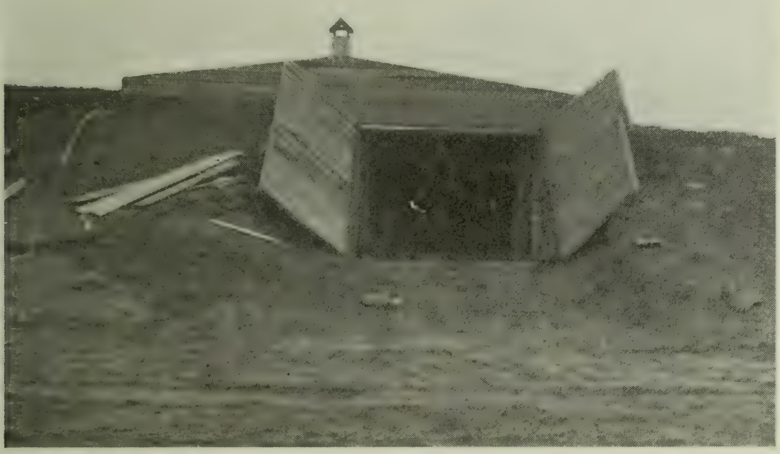


FIG. 17.—Root-cellar at Fredericton, N.B.

For satisfactory storage temperatures should be maintained between 32 and 38° F. Sudden and extreme temperature changes are the cause of greater loss than continued low temperatures, even when the latter run for considerable periods below the freezing-point of roots. Mangels, sugar beets and carrots will stand considerable freezing provided they are not handled when frozen and that the frost is allowed to come out gradually. Stored roots must not be allowed to dry out, drying being one of the principal causes of loss in cellar storage.

Root-pits take many shapes and forms. We have had some years as much as 3,000 feet of 5-foot pits divided up into lengths of from 10 to 65 feet, and have tried out many schemes for ventilating, piling and covering. Our conclusion is that the simpler the pit construction, the greater the chance for success. Pits with elaborate systems of ventilation, piling and covering have not only proven expensive to construct, but very unsatisfactory in results obtained.

The location of pits should be on well-drained land; a sandy knoll or side hill being ideal. After locating a suitable site, a trench is dug 10 to 20 inches deep and 4 to 6 feet wide, with the length depending on the amount of storage room desired. For small roots a width of 4 feet is sufficient, while 6 feet is not too wide for the storage of large roots. For convenience in construction and maintenance pits should not be longer than five to six times the width.

When removing earth for the pit bottom it should be thrown back on both sides about 4 feet from the edge of the pit where it will not interfere with the filling of the pit and will be convenient for subsequent use. Ventilators are constructed from four 6- to 8-inch boards nailed together to form a square pipe. On opposite sides 4- to 6-inch openings are left or cut out about a foot apart.

As roots are drawn they should be dumped either in the pit or beside it and forked in, care being taken to discard all broken or damaged roots as such roots start rotting and cause trouble during the winter. The roots should be piled so that they come to a peak at a height of 24 to 36 inches above ground level. No special order in piling is necessary and trouble taken to place tops out or otherwise on sides and ends is not only unnecessary but inadvisable. As roots are piled in, the upright ventilators are put up along the centre of the pit, the width apart being the same distance as the width of the pit, with the end ventilator about one-half the width of the pit from the end. The openings in the ventilator should be placed lengthwise to the pit and not extend higher than the top level of the first layer of straw. With ventilators in place and roots piled the pit should be covered with a little straw and left for a few days. If sheets are available they can be used to protect the pit from rain at this period. Leaving the pit with but a shallow protection of straw allows surface moisture to evaporate and the base of the leaf stems to dry out. The straw prevents sunburn of the roots. When the roots have sweated sufficiently, the covering of straw is increased to one foot, which depth will pack to about 6 inches, and the whole surface of the pile, except a foot along the centre, covered with 6 to 10 inches of earth. Earth taken out of the trench is used for this purpose. The additional earth necessary is removed from a trench not closer than 4 feet from the edge of the pit. The opening along the centre of the pit is protected by covering with two boards nailed in the shape of a V and inverted. This opening along the top allows for further loss of heat in the pits and can be left, protected by the V-shaped boards until the pit is cool and dry. The boards are then removed and the opening covered with earth. It is advisable to put a few inches of manure in the trench around the pit where earth has been removed for the first covering as this keeps the frost out of the trench, and makes the digging much easier for the second covering.

With the first layer of earth in place the pit should be left until this covering is frozen sufficiently to bear the weight of a man, after which the final covering is put on, about 6 to 8 inches of straw and the same of earth being used.

Some care should be given pits during the winter as even with the best construction trouble may start. If the pits are under observation any trouble can usually be rectified before serious damage results. Thermometers hung down the inside of the ventilators should be used in order that the temperatures in the pits may be known. We use one thermometer to every three ventilators, moving them around to different ventilators from time to time. If there is rotting in the pits a continued and definite rise in temperature will result, and by moving the thermometers to ventilators near the higher temperature the source of trouble can be definitely located. With the source located an opening can be made and the cause, generally the result of a damaged or rotten root, can be removed. Old bags nailed to hang from the ventilator tops are handy for controlling pit temperatures. Normally ventilator tops are left open, but if continued severe cold weather sets in the bags can be used to plug the ventilator; similarly when thaws occur the ventilators are plugged to hold the pit

FIG. 18.—Root-pit. Partly filled trench; method of piling to centre; and ventilators in position.

FIG. 19.—Root-Pits. First covering of earth and straw being put on. V-shaped boards protecting top of pit are remvoed when pit is dry and cool.

FIG. 20.—Root-Pits. Final covering of straw and earth being put on. Bags on ventilators for control of temperatures.

temperatures down or from rising from below freezing to normal temperature too fast. Protection against thaws is particularly necessary in the spring, and with properly constructed pits and correct use of ventilators temperatures below 40° F. can be maintained for short periods when day temperatures may range up to 60°. Our experience has been that trouble does not come from freezing, even though roots may remain frozen for weeks, but from sudden extreme temperature changes, particularly when frozen roots are thawed out rapidly. Ventilator plugs and thermometers are a cheap and reliable method of holding temperatures constant within the pits. In pits at Ottawa filled in October we have kept mangels as late as the last week in June, and had then come out as fresh, crisp and vital as the day they were pulled.

Carrots have kept equally well notwithstanding the fact that we have allowed and maintained temperatures below 15° F. for weeks during the winter.

In the spring the outer covering of earth and straw should be removed only when the frost starts to come out of the inside covering. This can be determined by driving a bar through the outside covering and testing the solidness of the inside covering of earth. Even when the outer layer is thawed it acts as a protection for the inner layer and helps to keep the pits cool after the outside temperatures continue above freezing.

Planting in the spring should be carried out as early as possible and the pits opened and the necessary selection made before planting time. When opened, all roots should be gone over carefully and all damaged or rotten roots discarded. As the growth which is to produce the seed comes from the crown, particular care should be taken that no roots with damaged crowns are set out. In the case of mangels, sugar beets and carrots, growth and seed production will as a rule result even when the crowns are considerably damaged, but almost invariably the planting of roots with damaged crowns is associated with a retarded and uneven production of seed. In the case of swedes, damage to or breaking off of the bud has generally resulted in very unprofitable stands. In quarter-acre blocks of mangels, carrots and swedes, the mangels and carrots with damaged crowns produced fair seed crops, but were late and uneven in maturing. Swede turnips with broken buds, although otherwise sound, did not produce a crop worth harvesting.

In selecting roots from the pits only typical roots of the variety should be saved and from these a further selection can be made by using the brine test. This method makes use of specific gravity in determining the relative dry-matter content of the roots to be tested. While it does not give the actual percentage of dry matter, it is a simple and fairly reliable method of grading field roots on their relative dry-matter content.

In operation the brine test is carried out as follows: as general selection is made a number of even-sized and most typical roots are put to one side. A tub or vat is filled with water, and salt is added to make a 4 or 5 per cent solution. The specially selected roots are placed in the brine a few at a time and those which sink are put aside as having a higher specific gravity than those which float. When all the roots selected have been tested the strength of the solution can be increased by adding more salt and further selection made. By still further increases in the strength of the brine the desired number of roots can be obtained possessing the highest relative dry-matter content. These roots can be used by the grower to produce stock seed for his own use and for further selection. The brine test should be made just previous to planting and it is advisable to wash the roots in fresh water before setting them out.

In selection before planting, roots should be roughly graded as to size and those of approximately the same size planted together in the field. As a rule, the larger roots mature seed earlier than smaller ones. If roots of different sizes are mixed in planting the maturing of seed is uneven and harvesting consequently made more difficult. When put in blocks according to the size of the root each entire block can be harvested when the seed is ready for cutting.

Small quantities of roots can be put in with a spade. With one man digging and another planting this method is fairly fast. When a considerable area is to be planted, the quickest way is to set in the roots following a plough. In planting with a plough the roots are set in every third furrow and covered

FIG. 21.—Mangels for seed being set in furrow.

FIG. 22.—Planting mangels for seed. A single-furrow plough covers the roots. A two-furrow plough follows, roots being again set in the third furrow.

with the fourth furrow-slice turned. Roots should be set in at a slight angle and the earth well firmed in around them. Where roots are set out in the fall, the crown should be 1 to 2 inches below the level of the ground. When set out in the spring, the top of the crown should be level with the ground.

The distance apart for roots in the row may vary slightly with the size of the roots; the smaller roots can be planted closer than large ones. The distance between rows should be sufficient to allow for maximum horse cultivation. Rows 3 feet apart have proven with us the most satisfactory. In the case of carrots, an extra wide roadway should be left every three or four rows to facilitate going through the fields at harvest time. Mangels and swedes should

FIG. 23.—Mangels set in furrow after two-furrow plough.

be $1\frac{1}{2}$ to 2 feet, and carrots 1 to 2 feet apart in the row. The distance between plants has a great influence on the seed yield and while planting $2\frac{1}{2}$ and 3 feet apart each way will facilitate cultivation and harvest, the consequent loss in yield is serious. In a test with mangels a number of roots of similar size were selected and set out in rows 3 feet apart with three different distances between plants in the row. Yields were obtained as follows:—

TABLE 18.—SEED ROOTS PLANTED AT VARYING DISTANCES APART

Distance between plants	Yield of seed, pounds per acre
3 by 3 feet	624
3 by 2 feet	690
3 by $1\frac{1}{2}$ feet	900

The influence of distances between roots is also shown in a preceding test on the comparison between small and large roots. (Table 17.)

The first period in the growth of the seed root is the production of new roots and leaf growth. This growth is made best in cooler weather and early planting before the weather gets excessively hot aids the root in establishing itself in its new location. The second period is the production of seed-stalks and seed; the second period depending on the success of the first. An unnatural forcing of the first period by late planting will materially decrease the success of the second period with consequent lowering of possible seed yields. To the prospective grower, possible seed yields are of interest, but owing to the many controllable and uncontrollable influences affecting yields, no definite estimate can be given.

The following are the average yields of seeds grown in Canada during a four-year period ending June, 1912:—

Mangels	1,200 lb. per acre
Swedes	1,000 " "
Field carrots	800 " "

In most cases during the time the Experimental Farms were growing field root seed as a war emergency these average yields were substantially exceeded.

Cultivation should be given to the seed root field as long as possible. So little time is available that all cultivation should be thorough. The very nature of growth renders all but early cultivation impossible and it should cease as soon as the seed-stalks begin to spread in the row.

Mangels are ready to harvest when the majority of the seed starts to turn brown. The top of the root just below the seed-stalks is cut off with a sharp spade and the crop tied up in small sheaves. When sheaves are tied they are butted; that is, the tops of the roots are cut off with a spade, and the sheaves then put up in small loose stooks until ready for threshing. With swedes the stalk is cut just above the crown, bound in sheaves and stooked until threshed.

Fig. 24.—Mangel seed crop.

The seed of mangels, sugar beets and turnips is readily lost by handling. For this reason cutting, binding and stooking is best done when dew is on the plants. A comparatively small amount spent on the purchase of large canvas or jute sheets will be more than repaid by the seed saved from being lost on the ground. When sheets are available, seed-stalks as cut are thrown on them and binding and butting carried out on the sheet. The sheets can be pulled along as harvesting proceeds and emptied into bags as necessary. Such seed collected on sheets must be spread out where drying conditions are good and allowed to cure. In handling from stook to thresher, sheets should at least be spread on the bottom of the wagon-rack and better still the whole stook turned on to a sheet and tied up. On the Experimental Farms all mangel and swede seed has

FIG. 25.—Harvesting mangel seed crop. The top of the root is cut just below the seed stalks.

FIG. 26.—Butting sheaves of mangels.

FIG. 27.—Mangel seed crop in stook.

FIG. 28.—Hauling mangel seed to thresher. The use of sheets saves a large percentage of seed.

been handled with the use of sheets and some rather startling results in saving seed obtained. In the case of mangels tied and butted on sheets, 12 per cent of the seed crop was salvaged on the sheets. In hauling from the field to the barn, stooks were turned on to sheets, tied up and then loaded. At the barn the material was forked off and that seed left in the sheets spread out to dry. After threshing, the threshed seed was also spread out to dry, and when dry both lots were cleaned and weighed up separately. The use of sheets resulted in saving 498 pounds of marketable seed where the total seed crop was 1,651 pounds. Such a saving would certainly warrant the use of sheets in connection with harvesting field root seeds.

Carrots, due to the fact that the individual seed-clusters do not ripen at the same time, cannot be harvested in the same manner as mangels and swedes. The individual seed-clusters must be picked by hand when they become brown and several pickings are necessary to harvest the crop in best condition. With carrots, harvesting may extend over a period of from two to three weeks. As collected the seed-clusters are spread out to a depth of 4 to 6 inches where drying conditions are good, and forked over several times to facilitate the thorough drying of the seed-heads.

Threshing of field root seed can be done with the ordinary thresher, it being advisable not to have the concaves close and if possible to remove every other row of teeth on the cylinder. The seed is not hard to thresh; the object being to break the stalks up as little as possible, as the removal of short pieces of stalk in cleaning requires a special machine in the case of mangels.

FIG. 29.—Harvesting swede seed crop. Stalks as cut can be piled on sheets.

When threshed, seed must be spread out and turned occasionally until it is dry enough for cleaning and bagging.

Special machines are required in getting mangel, sugar beet and carrot seeds ready for the market. From the two first-named crops all pieces of stalk must be removed. This separation is made with machines which take advantage of the fact that the seed is round whilst the sticks are more or less flat and

will not roll. The machine consists of a travelling endless belt set at an incline upon which the seed to be cleaned is fed. The seed, being round, will roll to the bottom, whilst sticks are carried on the belt and discharged at the side or top.*

Carrot seed has small spines and these cause the individual seeds to cling together so that before it can be cleaned and graded the spines must be removed by rubbing. There are several types of machines for this purpose. One type is a corrugated rubber-covered cylinder, with a fine wire, canvas or rubber

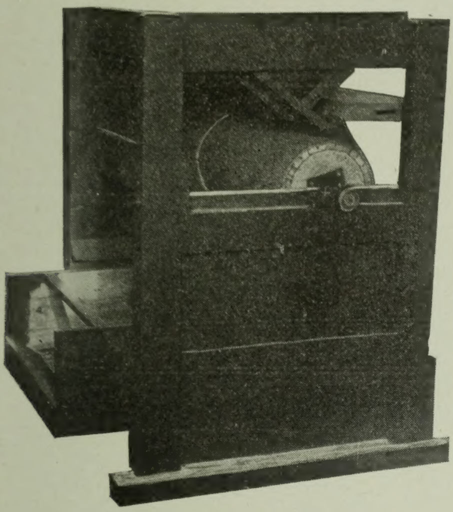


FIG. 30.

Carrot-seed rubber (part of case removed). A corrugated rubber-covered cylinder running against a canvas apron. Can be operated by hand or power.

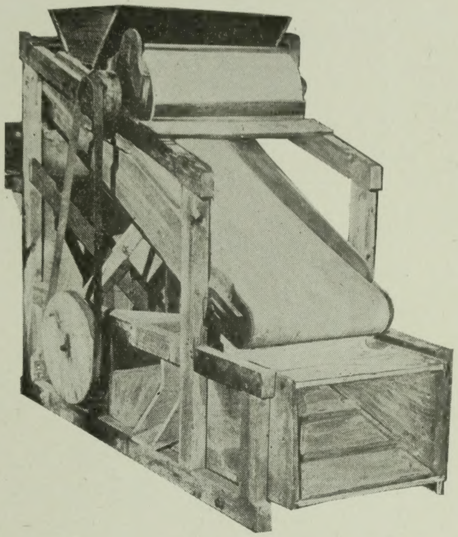


FIG. 31.

Small mangel seed-cleaning machine. Belt travelling upwards. The seed is fed on to belt near top and rolls to the bottom. Sticks are carried up by belt and discharged at top of machine.

apron to take the place of a concave; another used with excellent results is made of two endless belts running in contact but in opposite directions and at different speeds. In both machines the seed is rubbed between two surfaces and the spines removed, after which it can be cleaned and graded with a fanning-mill.

* Plans of small mangel and carrot seed cleaning devices can be obtained from the Division of Forage Plants, Central Experimental Farm, Ottawa, Ontario.

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